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Effective Microorganism Effect on the Growth and Yield of Spider Plant (*Cleome gynandra* L.)

Kerubo F.N[a]., *Okello S.V[a]., and Oluko P.S[b].
[a]*Kibabii University, Department of Biological Sciences, Environmental and Natural Resources P.O. Box 1699-50200, Bungoma, Kenya.*, [b]*Kibabii University, Department of Agriculture and Veterinary Sciences, P.O. Box 1699-50200, Bungoma, Kenya.*

Abstract
Cleome gynandra was tested under different Effective Microorganisms (EM) levels in a CRD greenhouse pot experiment. The study used two varieties (MSL-17 and MSL-F3), combined with five EM concentrations (EM 0, 50, 100, 150 and 200 g/L) on ferralsol soil in Kibabii. Normal agronomic management practices were carried out. Data was collected weekly on plant height, leaf area, leaf fresh and dry weight, days to 50% flowering, leaf number, soil microbial count, water and chlorophyll content. Spider plant varieties varied significantly (P≤0.05) in number of days to seedling emergence, local spider plant variety recorded lower seed germination than the exotic variety (MSL-F17). Plant height decreased by 7.0% with reduction in EM concentration level. Number of days to flowering was significantly affected (P≤0.05) by EM concentration level. Single leaf area significantly decreased (P≤0.05) with decline in EM concentration level for both varieties. Control (EM 0g/L) led to a significant reduction in spider plant single leaf area by 10.97%. Reduction of EM concentration level reduced chlorophyll content by 8.2 % across the varieties. Increased chlorophyll content due to increasing EM concentration level may be attributed to nutrient richness due to use of EM. High EM concentration level at EM 200g/L led to a significant (P≤0.05) reduction in spider plant single leaf area that could be attributed to significant (P≤0.05) increase in chlorophyll manufacture as well as plant cell turgor pressure. Leaf relative water content significantly decreased (P≤0.05) with reducing EM concentration. Increase in EM concentration significantly increased (P≤0.05) leaf yield by 25.7% and 14.0%, in exotic and local varieties respectively. Increased EM concentration at 200g/L significantly increased (P≤0.05) plant height, number of leaves per plant, single leaf area, chlorophyll content, leaf relative water content, and leaf yield. There exist significant genotypic differences in adaptation to EM concentration levels among the evaluated genotypes. Spider plant varieties varied significantly (P≤0.05) in agronomic traits, with variety MSL-17 at EM 200g/L, recording superior agronomic traits for growth, hence may be used for production and in the development of improved spider plants. MSL-F17 could be recommended for adoption by small scale farmers for direct production.
Keywords: *Cleome gynandra, varieties, genotypic, Effective Microorganisms*

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I. Introduction

Spider plant *(Cleome gynandra)* is used as both a vegetable and a medicinal plant and can be found in all over world. It grows as a weed in paddy fields and also in road sides and in open grass lands. In Kenya, the traditional leafy vegetables commonly utilized include spider plant (*Cleome gynandra* L.), Nightshades (*Solanum scabrum; Solanum scabrum*) and amaranthus (*Amaranthus hibridus)* cowpea (*Vigna unguiculata*), crotalaria (*Crotalaria brevidens*) Jute (*Corchorus olitorius*) [1].

Spider plant is used as a vegetable where the tender shoots and leaves are boiled and eaten as herb, tasty relish, stew or side dish. The vegetable is a rich source of protein, and the leaves contain over and above the normal recommended adult daily allowance of vitamins A and C and the minerals calcium and iron [1]. Boiling the leaves may reduce vitamin C content by up to 81% and drying can reduce vitamin C content further by 95% [2].

Continuous cultivation with little or no fertilizer application has often been associated with a decline in soil fertility with subsequent reduction in crop yields. The degradation is brought about by loss of organic matter which consequently results in soil acidity, nutrient imbalance and finally low crop yields. However, the use of inorganic fertilizers alone may cause problems for human health and environment [3]. In addition, excessive quantities of inorganic fertilizers are applied by farmers to vegetables to achieve a higher growth and yield as they are considered a major source of plant nutrients. The increase of inorganic fertilizers globally calls for a speedy intervention where high and sustainable vegetable yields can be obtained and maintained by promoting the use effective microorganisms (EM) that aid use of organic nitrogen that is capable of supplying fertilizer [6].

Beneficial microorganisms perform essential functions in agricultural systems, but as they are not visible to the naked eye, they are often overlooked. Reliance on indigenous microorganisms may produce variable results, depending on the spores present on the materials to be fermented, or in the fermenting vessel, or in the air. Effective Microorganisms (EM) is a commercial product that ensures greater consistency of microbial species composition and enhanced effectiveness of agricultural applications. It is a liquid containing different types of naturally occurring microorganisms, principally a consortium of lactic acid bacteria, yeasts and phototrophic bacteria that create the right conditions for mutual support, enabling them to outcompete harmful pathogens, while producing useful substances such as vitamins, enzymes, hormones, amino acids and anti-oxidants that create reducing environment [4, 8].

Effective Microorganisms (EM) can serve as alternative practice to minimize the use of mineral fertilizers as they aid in improving soil structure, water holding capacity, nutrient recycling, nutrient manufacture from organic matter, increase soil organic carbon and microbial biomass [5]. They also provide breakdown and availability of significant quantities of major and micro nutrients, and have a persistent effect on the soil over years. The way in which EM functions is not entirely understood. This study therefore, was conducted to assess the growth and yield of different spider plant varieties, with different levels of Effective Microorganisms (EM) in a ferralsol. The broad objective of the study was to determine the influence of Effective Microorganisms (EM) and EM concentration levels on the level of plant growth and development, yield and soil of two selected varieties of spider plant. Specifically, the study sought to; evaluate the effects of Effective Microorganisms (EM) and EM concentration levels on yield, growth and development of spider plant; and, to evaluate the effects of Effective Microorganisms (EM) and EM concentration levels on soil quality using spider plant [10,11] The study hypothesized that; Application of Effective Microorganisms (EM) and EM concentration levels do not influence the yield, growth and development of spider plant of the two varieties of spider plant; and, Application of Effective Microorganisms (EM) and EM concentration levels does not influence the soil properties of the two varieties of spider plant.

II. Materials and Methods

The study was carried out in Bungoma county, in Kibabii university, located on 0.5699° N, 34.5593° E between June -October 2021.

The study involved the use a greenhouse pot experiment, using ferallsol as the only type of soil. The research used Effective Microorganisms (EM) on Spider plant (*Cleome gynandra* L.).

Experimental Treatments

Two varieties of Spider plant (*Cleome gynandra* L.) were sourced from farmers (local variety) while another was sourced from Kenya Seed company (Exotic variety). The two were identified as MSL-F17 (exotic variety) and MSL-F3 (local variety). Effective Microorganisms (EM) was applied in the soil at planting spider plant (*Cleome gynandra* L.) varieties. This was applied at five levels or concentrations. These were; EM 0g/L -control, EM 50g/L, EM 100g/L, EM 150g/L, and EM 200g/L. This was replicated three times. Seeds were planted in 2kg soil filled pots, and thinning and other agronomic practices were done accordingly. Three seedlings were maintained in the pot that contained 2 kg of soil after thinning.

Experimental Design

The study used a Complete Randomized Design (CRD) having 2 treatments which are the effective microorganisms (EM) (at 5 levels) and spider plant varieties (2 varieties). This was replicated three times in ferralsol soil.

Data Collection

Data was collected every week on plant height (cm), leaf length, leaf width, fresh and dry weight of the shoots, leaf number, days to 50% flowering, and chlorophyll content. At end of experiment, data was collected on Leaf Area Index (LAI), water content, yield, soil pH, and soil bacterial spore count. Number of days from sowing to seedling emergence was determined by

recording the number of days when 50% of the seedlings had emerged. Seedling vigor was determined at day seven according to [6].

$$V = Sx \sum \left(\frac{Gt}{Dt}\right)$$

Where; S -seedling height of the seventh day, Gt -number of germinated seeds in the "tth" day, (7TH day); Dt -number of days from the first day to the "tth" day (7 days)

Length (L) of the leaf from the base to the tip and width at the widest part of the blade (W) of the central leaflet were recorded and single leaf area (SLA) (cm^2) calculated following the formulae of [7]: SLA=0.763L +0.34W. The Leaf Area Index was calculated using the formula described by [8]. Leaf Area = (L x W) x (0.67); where L-length and W-width of individual leaf. Leaf Area Index (LAI) was computed using the formula given by [8]. LAI = (Leaf Area/land surface area occupied by the plant from where the leaf area was obtained).

Data analysis.
Data obtained were subjected to the general analysis of variance employing CRD design, using GENSTAT statistical software, version 19 [9] to check for main effects of treatments - EM concentration levels Duncan's Multiple Range tests [10] was used to identify and separate significant differences among treatment means ($P<0.05$).

Results

Treatment effect on percentage germination and seedling vigor
Exotic variety recorded a high percentage germination and seed vigor (Table 4.1). Treatments had no significant effect on percentage germination and seed vigor (Table 4.1). There was an increased percentage germination under increased treatments of EM concentration (Table 4.1).

Table 4.1: Effect of treatments on Percentage germination and seedling vigor

Variety	EM Concentration	% Germination	% Seedling Vigor
Exotic (MLSF-17)	EM 0ml/L	60.01a	65.74a
	EM 50ml/L	86.67a	92.41a
	EM 100ml/L	83.33a	89.08a
	EM 150ml/L	86.67a	92.41a
	EM 200ml/L	86.67a	92.41a
	Mean	***72.00***	***75.74***
Local (MLS-F3)	EM 0ml/L	50.00a	53.74a
	EM 50ml/L	80.00a	83.74a
	EM 100ml/L	70.00a	73.74a
	EM 150ml/L	76.67a	80.41a
	EM 200ml/L	83.33a	87.08a
	Mean	***72.00***	***75.74***
	Grand Mean	***76.33***	***81.08***
		e.s.e.	***e.s.e.***
	VAR	5.66	5.657
	TRT	8.94	8.944
	VAR*TRT	12.65	12.649
	%CV	18.7	27.1

**Means with the same letter do not differ significantly*

Treatment effect on plant height (cm)
Generally, the exotic variety MLS-17, recorded higher plant height means as compared to the local variety MLS-F3 (Table 4.2).

Table 4.2: Effect of EM treatments on Plant height (cm)

			Plant Height (cm)							
Variety		EM Concentration	PHWK3	PHWK4	PHWK5	PHWK6	PHWK7	PHWK8	PHWK9	Mean
Exotic (MLSF17)		EM 0ml/L	31.41d	33.23cd	34.23b	37.24c	39.21c	40.41c	42.64c	***36.89***
		EM 50ml/L	28.81c	29.73b	32.93b	31.73b	33.53b	34.93b	37.53b	***32.74***
		EM 100ml/L	37.33e	38.33e	39.63e	40.87d	42.26d	43.53def	44.87cd	***40.96***
		EM 150ml/L	42.22f	43.22f	44.25f	45.22e	46.13ef	46.93g	48.13e	***45.14***
		EM 200ml/L	42.61f	43.23f	44.62f	45.63e	46.61f	46.47fg	48.47e	***45.36***
		Mean	***36.466***	***37.532***	***39.106***	***40.120***	***41.532***	***42.452***	***44.320***	***40.22***
Local (MLSF3)		EM 0ml/L	18.42a	21.26a	24.43a	25.23a	27.22a	29.22a	31.02a	***25.23***
		EM 50ml/L	25.27b	31.13bc	36.73cd	40.93d	42.23d	42.93cde	45.21d	***37.77***
		EM 100ml/L	30.47cd	34.33d	38.97de	41.93d	44.34def	45.33efg	47.47e	***40.40***
		EM 150ml/L	30.13cd	32.87cd	38.13cde	42.42d	43.93de	45.23efg	49.87e	***40.36***
		EM 200ml/L	31.33d	33.23cd	36.42c	37.07c	38.82c	40.67cd	42.87cd	***37.19***
		Mean	***27.120***	***30.546***	***34.926***	***37.506***	***39.286***	***40.666***	***43.282***	***36.19***
		Grand Mean	**31.790**	**34.040**	**37.020**	**38.810**	**40.410**	**41.560**	**43.800**	
			e.s.e.	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	
		VAR	*0.31*	*0.338*	*0.351*	*0.352*	*0.376*	*0.438*	*0.359*	
		TRT	*0.49*	*0.535*	*0.555*	*0.557*	*0.594*	*0.693*	*0.567*	
		VAR*TRT	*0.693*	*0.757*	*0.784*	*0.787*	*0.84*	*0.98*	*0.802*	
		%CV	8.4	8.6	8.2	7.9	8.1	9.1	7.1	

**Means with the same letter do not differ significantly*

At week 9, the plant height was significantly high (P≤0.05) above the local variety, with 44.32cm and 43.282cm respectively. Overall mean of MSL-17 was higher than that of local variety (MSL-F3) (Table 4.2). Plant height of the rest of the weeks (week 4 to week 9) showed variety MSL-F3 increase in plant height at a slower rate as compared to exotic variety MSL-F17 (Table 4.2). Across the EM treatments, reduced plant height was recorded under control (EM 0ml/L). This however increased with an increase in the concentration of the EM (Table 4.2). The highest plant height mean was recorded under EM 200ml/L, and this was common in all the two tested varieties (Table 4.2).

Treatment effect on Leaf Length (cm)

Treatment level (EM concentration) and variety had a significant effect (P≤0.05) on spider plant leaf length (Table 4.3). Reduction of treatment concentration level from EM 200ml/L to EM 0ml/L significantly reduced leaf length in both varieties MSL-F3 and MSL-F17 (Table 4.3).

Table 4.3: Effect of EM treatments on Leaf Length (cm)

		Leaf Length (cm)							
Variety	EM Concentration	WK4	WK5	WK6	WK7	WK8	WK9	WK10	Mean
Exotic (MLSF-17)	EM 0ml/L	6.28f	6.32e	6.78e	6.841e	7.741f	7.412e	7.621e	***7.00***
	EM 50ml/L	5.547ef	5.74de	5.813de	6.153de	6.193de	6.641de	6.873de	***6.14***
	EM 100ml/L	4.94cde	4.967cd	5.253cd	5.00bcd	5.481cde	5.781cd	5.833cd	***5.32***
	EM 150ml/L	5.567def	5.86de	5.447cd	6.147de	6.727ef	6.642de	6.781de	***6.17***
	EM 200ml/L	4.213cd	4.24bc	4.66cd	4.273bc	4.661bc	4.993bc	5.133bc	***4.60***
	Mean	***5.309***	***5.425***	***5.591***	***5.683***	***6.160***	***6.291***	***6.448***	***5.844***
Local (MLS-F3)	EM 0ml/L	2.22a	2.38a	2.56a	2.700a	2.800a	3.021a	3.141a	***2.69***
	EM 50ml/L	2.76ab	3.053ab	3.33ab	3.667ab	3.947ab	4.053ab	4.453b	***3.60***
	EM 100ml/L	3.813bc	4.153bc	4.347bc	4.541bc	4.933bcd	5.211bc	5.587bcd	***4.65***
	EM 150ml/L	4.287cde	4.58cd	4.833cd	5.361cd	5.233cd	5.847cd	6.147cd	***5.18***
	EM 200ml/L	4.873cde	5.073cde	4.753cd	5.561cde	6.223de	5.607cd	5.827cd	***5.41***
	Mean	***3.591***	***3.848***	***3.959***	***4.365***	***4.623***	***4.745***	***5.031***	***4.309***
	Grand Mean	***4.500***	***4.600***	***4.800***	***5.000***	***5.400***	***5.500***	***5.700***	
		e.s.e.	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	
	VAR	0.19	0.19	0.2	0.2	0.19	0.2	0.28	
	TRT	0.3	0.3	0.32	0.31	0.29	0.31	0.44	
	VAR*TRT	0.43	0.42	0.45	0.44	0.42	0.44	0.62	
	%CV	37.2	35.2	36.3	34.2	29.9	31	29.7	

**Means with the same letter do not differ significantly*

Reduction of treatment concentration level significantly reduced leaf length in both varieties MSL-F3 and MSL-F17. Variety MSL-F17 had significantly higher leaf length (cm) than local variety (MSL-F3) (Table 4.3). Variety MSL-F3 had significantly lower leaf length than MSL-F17 variety (Table 4.3). Variety MSL-F17 had the highest mean leaf length (5.84 cm), while variety MSL-F3 had a lower mean leaf length (4.309 cm) (Table 4.3). Control treatment (EM 0ml/L) recorded the lowest mean leaf length across the two varieties MSL-F3 and MSL-F17. Generally, exotic variety had high leaf length across all treatment levels (Table 4.3).

Treatment effect on Leaf Width (cm)

Generally, exotic variety (MSL-F17) had high leaf width across all treatment levels as compared to local variety (MSL-F3) (Table 4.4). Control treatment (EM 0ml/L) recorded the lowest mean leaf width across the two varieties MSL-F3 and MSL-F17. The highest leaf width was recorded under treatment EM 200ml/L (Table 4.4). Treatment level (EM concentration) and variety had a significant effect (P≤0.05) on spider plant leaf width (Table 4.4). Increase of treatment concentration level from EM 0ml/L to EM 220ml/L significantly reduced leaf width in both varieties MSL-F3 and MSL-F17 (Table 4.4). Increase of treatment concentration level significantly reduced leaf width in both varieties MSL-F3 and MSL-F17 (Table 4.4). Variety MSL-F17 had significantly higher leaf width (cm) than local variety (MSL-F3) (Table 4.4). Variety MSL-F3 had significantly lower leaf width than MSL-F17 variety (Table 4.4). Variety MSL-F17 had the highest mean leaf width (4.052 cm), while variety MSL-F3 had a lower mean leaf width (2.169 cm) (Table 4.4).

Table 4.4: Effect of EM treatments on Leaf Width (cm)

		Leaf Width (cm)							
Variety	EM Concentration	WK4	WK5	WK6	WK7	WK8	WK9	WK10	Mean
Exotic (MLSF-17)	EM 0ml/L	1.911b	1.961b	1.962abc	2.262bc	2.161abc	2.361abc	2.561abc	***2.17***
	EM 50ml/L	3.373c	3.021c	3.321d	4.527d	4.627e	4.727ef	4.893d	***4.07***
	EM 100ml/L	4.353d	3.961d	4.387e	5.373e	5.553f	5.747g	5.987e	***5.05***
	EM 150ml/L	4.641d	4.907e	5.227f	3.742d	3.833d	4.101e	4.247d	***4.38***
	EM 200ml/L	3.433c	3.287c	4.173e	3.773d	5.527f	5.387fg	6.553e	***4.59***
	Mean	***3.540***	***3.427***	***3.813***	***3.935***	***4.340***	***4.464***	***4.848***	**4.052**
Local (MLS-F3)	EM 0ml/L	1.061a	1.211a	1.341a	1.441a	1.523a	1.621a	1.722a	***1.41***
	EM 50ml/L	1.962b	2.102b	2.193bc	2.361bc	2.502bc	2.562bcd	2.662bc	***2.33***
	EM 100ml/L	1.382ab	1.562ab	1.587ab	1.713ab	1.827ab	1.922ab	2.161ab	***1.74***
	EM 150ml/L	1.933b	2.087b	2.467c	2.721c	2.787c	2.987cd	3.173c	***2.59***
	EM 200ml/L	2.120b	2.253b	2.653cd	2.8532c	2.973c	3.173d	3.342c	***2.77***
	Mean	***1.691***	***1.840***	***2.048***	***2.217***	***2.321***	***2.452***	***2.611***	**2.169**
	Grand Mean	***2.600***	***2.600***	***2.900***	***3.100***	***3.300***	***3.500***	***3.700***	
		e.s.e.	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	***e.s.e.***	
	VAR	0.11	0.1	0.11	0.12	0.12	0.12	0.13	
	TRT	0.18	0.16	0.17	0.19	0.19	0.19	0.21	
	VAR*TRT	0.25	0.23	0.24	0.27	0.27	0.27	0.29	
	%CV	37.4	34.2	32.0	34.5	31.7	29.8	30.3	

**Means with the same letter do not differ significantly*

Treatment effect on Leaf Area Index (cm)

Leaf area index was high under exotic variety, and this increased with increasing treatment concentration level which was significantly high ($P \leq 0.05$) above the control treatment (Table 4.5). Leaf area index significantly decreased with reduced EM concentration level both MLS-F3 and MLS-F17 (Table 4.5).

Table 4.5: Effect of EM treatments on Leaf Area Index (cm)

Variety	EM Concentration	Leaf Area Index
Exotic (MLSF-17)	EM 0ml/L	6.684de
	EM 50ml/L	6.908e
	EM 100ml/L	6.486de
	EM 150ml/L	6.617de
	EM 200ml/L	6.145de
	Mean	***6.568***
Local (MLS-F3)	EM 0ml/L	2.981a
	EM 50ml/L	4.302b
	EM 100ml/L	4.997bc
	EM 150ml/L	5.769cde
	EM 200ml/L	5.581cd
	Mean	***4.726***
	Grand Mean	***5.647***
		e.s.e.
	VAR	0.1617
	TRT	0.2556
	VAR*TRT	0.3615
	%CV	24.8

**Means with the same letter do not differ significantly*

Variety MSL-F17 had a higher leaf area index than all the MSL-F3 at EM 200ml/L concentration levels having 6.145de and 5.581cd cm^2 (Table 4.5). Variety MSL-F3 was less responsive to reduction in EM concentration levels than MSL-F17 (Table 4.5). Average single leaf area ranged from 6.568 cm^2 (MSL-F17) to 4.726 cm^2 (MSL-F3). Average decrease in leaf area ranged from 2.981a cm^2 (local variety) to 6.684 cm2 (exotic variety) under control treatments (Table 4.5).

Treatment effect on Days to 50% flowering

Treatment level and variety significantly (*$P \leq 0.05$*) affected the number of days to flowering in spider plant (Table 4.6). Reduction of treatment concentration level from EM 0ml/L to EM 220ml/L significantly reduced the number of days to flowering in all varieties (MSL-F17 and MSL-F3) (Table 4.6). Reduction of treatment concentration level from EM 150ml/L to EM 220ml/L significantly reduced the number of days to flowering for MSL-F3 but had no effect on MSL-F17 (Table 4.6).

Table 4.6: Effect of EM on number of Days to 50% flowering of spider plant

Variety	EM Concentration	Days to 50% flowering
Exotic (MLSF-17)	EM 0ml/L	65.004e
	EM 50ml/L	64.331d
	EM 100ml/L	63.332c
	EM 150ml/L	62.671b
	EM 200ml/L	62.002a
	Mean	63.466
Local (MLS-F3)	EM 0ml/L	74.662j
	EM 50ml/L	74.003i
	EM 100ml/L	73.332h
	EM 150ml/L	71.671g
	EM 200ml/L	66.001f
	Mean	71.932
	Grand Mean	67.700
		e.s.e.
	VAR	0.0817
	TRT	0.1291
	VAR*TRT	0.1826
	%CV	5.5

**Means with the same letter do not differ significantly*

Variety MSL-F17 recorded the lowest number of days to flowering at EM 220ml/L (62.002[a] days) while variety MSL-F3 recorded the highest average number of days to flowering at EM 0ml/L with 74.662[j] days (Table 4.6). Compared to control (EM 0ml/L), increased EM concentration reduced days to flowering by 4.7%, in EM 200ml/L. Reduction of treatment concentration from EM 200ml/L to EM 0ml/L increased the number of days to flowering by 6.9 days in MSL-F3 and 3.0 days in MSL-F17 (Table 4.6).

Treatment effect on number of flowers

Variety and EM concentration level significantly influenced the number of spider plant flowers per plant (Table 4.7). Reduction in EM concentration level to EM 100ml/L and below significantly reduced the number of leaves per spider plant for all varieties (MSL-F17 and MSL-F3) (Table 4.7).

Table 4.7: Effect of EM on number of flowers per spider plant

Variety	EM Concentration	No. of Flowers
Exotic (MLSF-17)	EM 0ml/L	6.335b
	EM 50ml/L	9.666e
	EM 100ml/L	11.331f
	EM 150ml/L	11.664f
	EM 200ml/L	12.663g
	Mean	***10.332***
Local (MLS-F3)	EM 0ml/L	5.336a
	EM 50ml/L	6.668bc
	EM 100ml/L	7.334cd
	EM 150ml/L	7.001bcd
	EM 200ml/L	7.668d
	Mean	***6.801***
	Grand Mean	***8.567***
		e.s.e.
	VAR	0.1033
	TRT	0.1633
	VAR*TRT	0.2309
	%CV	10.4

**Means with the same letter do not differ significantly*

Increase of EM concentration level from EM 100ml/L to EM 200ml/L significantly increased the number of spider plant leaves per plant in all varieties. At EM concentration level from EM 200ml/L, variety MSL-F17 recorded a higher leaf number per plant (12.663g) than the local variety (saga) while at 40 % FC accessions Kuria and Mombasa recorded a higher leaf number of leaves per plant than the commercial variety (MSL-F3) having 7.668d (Table 4.7). Average number of leaves per plant ranged from 10.332 (MSL-F17) to 6.801 (MSL-F3). Variety MSL-F17 recorded the highest number of leaves at all EM concentration levels (Table 4.7).

Treatment effect on shoot fresh and dry weight (g)

Variety and EM concentration level significantly ($P \leq 0.05$) affected spider plant fresh shoot weight (Table 4.8). Shoot fresh weight (g) per plot significantly reduced with increase in reduction of EM concentration level. This was the trend in both the varieties MSL-F17 and MSL-F3 (Table 4.8). Reduction of EM concentration level from EM 200ml/L to EM 100ml/L did not significantly reduce shoot fresh weight for varieties MSL-F17 and MSL-F3. While reduction of EM concentration had no significant effect on MSL-F3 variety (Table 4.8). Reduction of EM concentration from EM 200ml/L to EM 100ml/L significantly reduced shoot fresh weight for varieties MSL-F17 and MSL-F3. Average shoot fresh weight ranged from 7.571a-11.732c g (MSL-F3) to 13.692d-23.382g g(MSL-F17). At EM 100ml/L variety MSL-F17 recorded significantly higher ($P \leq 0.05$) shoot fresh weight than the MSL-F3 variety (Table 4.8).

Table 4.8: Effect of EM on number of flowers per spider plant

Variety	EM Concentration	Fresh Weight Shoot (g)	Dry Weight Shoot (g)	Water Content (g)
Exotic (MLSF-17)	EM 0ml/L	13.692d	7.464d	6.226
	EM 50ml/L	18.172e	8.887e	9.283
	EM 100ml/L	20.212f	10.048f	10.152
	EM 150ml/L	19.342ef	9.472f	9.868
	EM 200ml/L	23.382g	9.709f	13.671
	Mean	***18.956***	***9.116***	***9.84***
Local (MLS-F3)	EM 0ml/L	7.571a	4.433a	3.137
	EM 50ml/L	8.282a	5.024b	3.256
	EM 100ml/L	8.771a	5.152b	3.618
	EM 150ml/L	10.383b	6.375c	4.005
	EM 200ml/L	11.732c	7.079d	4.651
	Mean	***9.346***	***5.613***	***3.7334***
	Grand Mean	***14.152***	***7.364***	
		e.s.e.	***e.s.e.***	
	VAR	*0.1961*	*0.0883*	
	TRT	*0.31*	*0.1397*	
	VAR*TRT	*0.4384*	*0.1975*	
	%CV	12	10.4	

**Means with the same letter do not differ significantly*

Reduction of EM concentration level from EM 200ml/L to EM 100ml/L significantly reduced shoot dry weight for varieties MSL-F17 and MSL-F3 (Table 4.8). Reduction of EM concentration from EM 200ml/L to EM 100ml/L significantly reduced shoot dry weight for both varieties MSL-F17 and MSL-F3 (Table 4.8). Average shoot dry weight ranged from 4.433^{a}-7.079^{d} g (MSL-F3) to 7.464^{d}-9.709^{f} g(MSL-F17). At EM 100ml/L variety MSL-F17 recorded significantly higher ($P \leq 0.05$) shoot dry weight than the MSL-F3 variety (Table 4.8). Variety and EM concentration level significantly ($P \leq 0.05$) affected spider plant dry shoot weight (Table 4.8). Shoot fresh weight (g) per plot significantly ($P \leq 0.05$) reduced with increase in reduction of EM concentration level (Table 4.8). This was the trend in both the varieties MSL-F17 and MSL-F3 (Table 4.8).

Variety x EM concentration level significantly ($P \leq 0.05$) affected leaf relative content in spider plant (Table 4.8). At high EM concentration of EM 200ml/L, variety MSL-F17 recorded the highest relative water content of 13.671g (Table 4.8). Reduction of EM concentration of EM 200ml/L to EM 100ml/L level did not have a significant effect on leaf relative water content for MSL-F17 and MSL-F3 (Table 4.8). At EM concentration of EM 200ml/L, exotic variety MSL-17 had higher leaf relative water content than the local variety (MSL-F3) (Table 4.8).

Treatment effect on spider plant leaf yield per plot

Variety and EM concentration level significantly ($P \leq 0.05$) affected spider plant leaf yield per plot (Fig 4.1). Leaf yield per plant significantly reduced with increase in reduction of EM concentration (Fig 4.1). Reduction of moisture level from EM 200ml/L to EM 100ml/L significantly reduced leaf yield for varieties MSL-F17 and MSL-F3 (Fig 4.1).

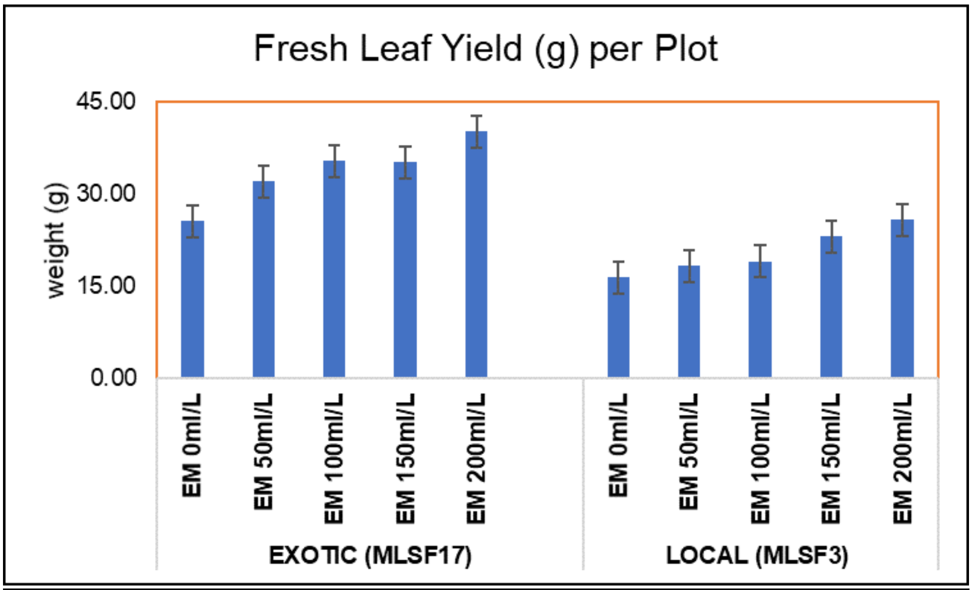

Fig 4.1: Effect of EM on spider plant yield

Average leaf yield was 33.686g per plot (MSL-F17) to 20.568g per plot (MSL-F3). At EM 200ml/L concentration, exotic variety (MSL-F17) had higher leaf yield than local variety (MSL-F3) (Fig 4.1).

Treatment effect on spider plant leaf chlorophyl content

The EM 200ml/L significantly reduced ($P \leq 0.05$) chlorophyll content in all varieties. The EM 200ml/L significantly reduced chlorophyll content of MSL-F17 variety in the study (Table 4.9). At EM 200ml/L, MSL-F17 recorded the highest chlorophyll content at 2.050h g/l (Table 4.9). At EM 200ml/L, variety MSL-F17 recorded a significantly higher ($P \leq 0.05$) chlorophyll content than the local variety (MSL-F3) (Table 4.9). Varieties and treatment (EM Concentration) interaction level significantly affected the chlorophyll content in spider plant (Table 4.9).

Table 4.9: Effect of EM on spider plant leaf Chlorophyl content

Variety	EM Concentration	Chlorophyll (g/l)
Exotic (MLSF-17)	EM 0ml/L	1.294b
	EM 50ml/L	1.494e
	EM 100ml/L	1.679f
	EM 150ml/L	1.886g
	EM 200ml/L	2.050h
	Mean	***1.681***
Local (MLS-F3)	EM 0ml/L	1.256a
	EM 50ml/L	1.227a
	EM 100ml/L	1.229a
	EM 150ml/L	1.363c
	EM 200ml/L	1.432d
	Mean	***1.301***
	Grand Mean	***1.491***
		e.s.e.
	VAR	*0.00457*
	TRT	*0.00722*
	VAR*TRT	*0.01021*
	%CV	2.7

**Means with the same letter do not differ significantly*

Treatment effect on soil pH

The EM 200ml/L significantly increased ($P \leq 0.05$) soil pH variety MSL-F17, from 4.527^{bcd} to 5.075^{e} (Table 4.9). The EM 200ml/L significantly ($P \leq 0.05$) soil pH variety MSL-F3 (Table 4.9).

At EM 100ml/L, variety MSL-F17 recorded a lower soil pH under exotic variety (MSL-F17) than the local variety (MSL-F3) (Table 4.9). Varieties and treatment (EM Concentration) interaction level significantly affected the soil pH (Table 4.9).

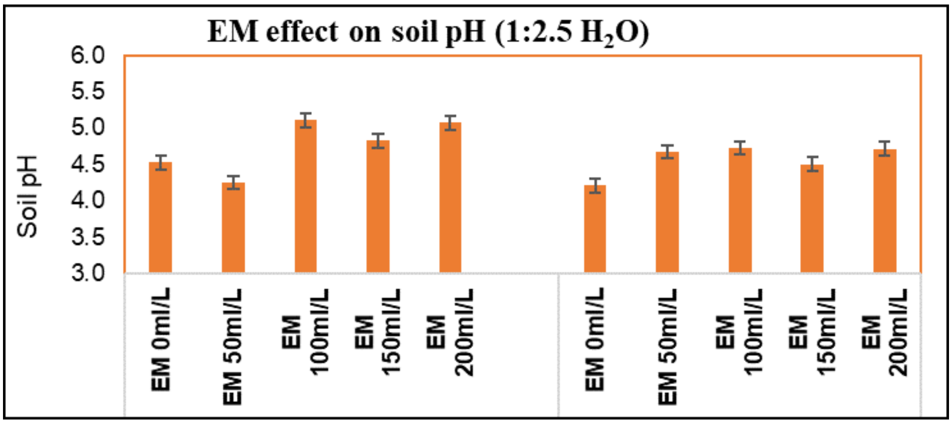

Fig 4.2: Effect of EM on soil pH

Treatment effect on soil microbial count

An increase of EM concentration level from EM 0ml/L to EM 200ml/L resulted into an increased bacterial spore count for varieties MSL-F17 and MSL-F3 (Fig 4.3). The EM concentration from EM 200ml/L yielded higher bacterial spore counts for both varieties MSL-F17 and MSL-F3 (Fig 4.3). Average bacterial spore counts ranged from 103.278[a]-349.185[d] spores g^{-1} of soil (MSL-F17) to 102.103[a]-341.267[d] spores g^{-1} of soil (MSL-F3). Bacterial spore counts g^{-1} of soil significantly ($P \leq 0.05$) reduced with decrease in EM concentration level (Fig 4.3). This was the trend in both the varieties MSL-F17 and MSL-F3 (Fig 4.3).

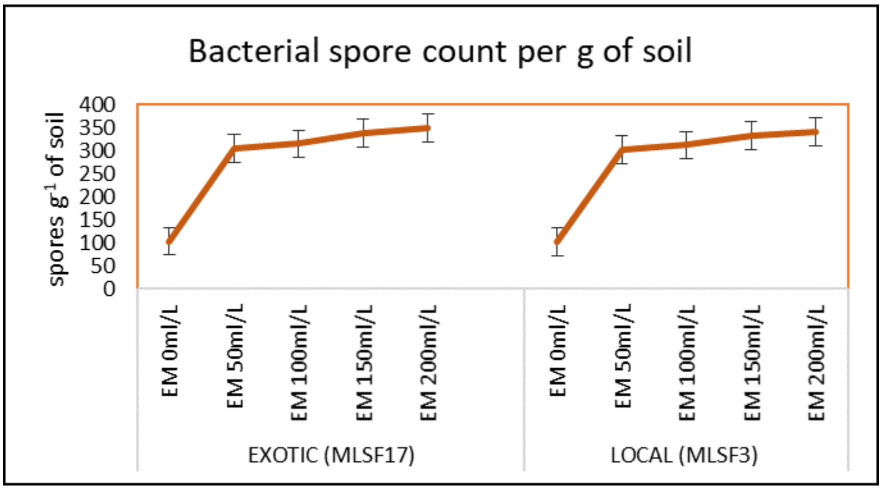

Fig 4.3: Effect of EM on soil microbial count

General overview of results

The findings of the current study show that use of EM increases soil microbial richness. From other studies however, the low soil pH recorded from this study is related to acidity, and acidic soil is attributed to ionizing free ammonia in water to ammonium ion which is not friendly to nematodes and other microorganisms [11], thus reduces its population. Synthetic fertilizers are also associated with increased pathogenic micro-organisms, decreasing beneficial micro-organism [12]. The findings by [13] reckoned that agricultural practices may have positive or negative impacts on micro-organisms in the soil. Also, micro-organisms in the soil interact with other factors stimulating the release of nutrients and organic matter necessary for crop growth. This could have been the reason behind improved crop plant height and leaf number, recorded under EM 200ml/L that resulted into increased bacterial spore count.

III. Discussion

Effect of EM on percentage Germination and Seed vigor

Spider plant accessions varied significantly ($P \leq 0.05$) in number of days to seedling emergence in the greenhouse pot experiment. This could be attributed to developmental stage at which the seeds were harvested and the way the seeds were processed. Spider plant seeds that are harvested when the pods have ripened and yellow have shown to exhibit high seedling vigor and emergence. Early harvesting results to seed dormancy and poor-quality seeds whose emergence tends to be low, which could be linked to the lower germination percentage of the local variety. Lack of expertise in seed processing and handling could have made farmers harvest their seed before maturity. Spider plant varieties sourced from farmers emerged later and had lower seedling emergence than exotic varieties. The delayed seedling emergence of exotic varieties may be attributed to long storage under very low temperatures that could result to dormancy and loss of viability. Generally, local spider plant variety recorded lower seed germination than the exotic variety (MSL-F17). The poor seedling emergence is partly attributed to poor processing before storage for farmers seed and long storage (more than 5 years) at low temperatures (-20^{0}C) for exotic varieties.

Spider plant varieties varied significantly ($P \leq 0.05$) in growth and yield parameters in greenhouse pot experiment. Variations observed among the spider plant varieties could be partly attributed to different evolutionary pathways of development as the varieties were sourced from different regions. Plant height decreased by 7.0% with reduction in EM concentration level. Data analysis showed that increase in EM concentration level corresponded to an increase in plant height. This may be attributed to positive effects of EM in nutrient supply as well as on cell expansion and elongation [14] [15]. Numerous studies have reported significant decrease in plant height due to EM application. [16] noted that plant height in tomato plant reduced by 22.3% with application of EM nutrient level.

Effect of EM on Days to 50% Flowering

Number of days to flowering was significantly affected ($P \leq 0.05$) by EM concentration level. This may be attributed to the fact that EM alters initiation and duration of the processes involved in conversion of vegetative meristems into floral parts. Prasad *et al*., (2008) reported that moderate EM concentration level reduces the length of time from flowering to anthesis which was the case for most varieties in the current study. However, it might be reduced under increased EM concentration level as recorded in MSL-F17 whose time to flowering was increased by 6.9 days. Similar findings were recorded by [14] in sorghum the flowering was delayed by 59 days under EM concentration level of 0.95g/l. Response to EM concentration level with respect to number of days to flowering varied with spider plant varieties, MSL-17 and MSL-F3. These variations may be attributed to the fact that the accessions were sourced from different sources with varying moisture stress conditions. Spider plant varieties grown in the 200ml/L EM concentration level were the earliest to flower, in both varieties tested.

Effect of EM on Leaf Area Index (LAI)

Single leaf area significantly decreased ($P \leq 0.05$) with decline in EM concentration level for both of the varieties. Control (EM 0g/L) led to a significant reduction in spider plant single leaf area by 10.97%. Leaf growth and development have been reported to be sensitive to both nutrients levels and moisture stress. Also, micro-organisms in the soil interact with other factors stimulating the release of nutrients and organic matter necessary for crop growth [19]. These results are in agreement with [9] who noted that leaf area of pigeon pea decreased by 22.5% with reduction in nutrients level, as a result of low microbial load in the soil. Impact of soil microbial count on single leaf area was dependent on the varieties. Exotic variety was highly responsive to increase in EM concentration level than local spider plant variety. For this reason, MSL-17 variety can be a suitable candidate for producing spider plant variety for vegetable production using EM at different concentration level.

Effect of EM on percentage spider plant leaf Chlorophyll content

Reduction of EM concentration level reduced chlorophyll content by 8.2 % across all the two varieties. Increased chlorophyll content due to increasing EM concentration level may be attributed to nutrient richness due to use of EM. This would have improved the pigment protein complexes which protect the photosynthetic apparatus or oxidative damage of chloroplast, lipids and proteins resulting in increased synthesis of chlorophyll a, b and carotenoids [12, 13]. These findings agreed with those of Sharafzadeh [5], and Higa [4] who reported that reduction in chlorophyll content under nutrients stress is a universally observed phenomenon. The interaction between spider plant varieties and EM concentration level was significant. At EM concentration level EM 200g/L, EM levels significantly ($P \leq 0.05$) increased chlorophyll content in all varieties. This may be attributed to collection of varieties from different sources (MSLF-17 and MSLF-F3) that exhibit varying handling, processing and storage methods, resulting to variations in adaptability to water stress among the genotypes.

High EM concentration level at EM 200g/L led to a significant ($P \leq 0.05$) reduction in spider plant single leaf area that could be attributed to significant ($P \leq 0.05$) increase in chlorophyl manufacture as well as plant cell turgor pressure. Reduction in EM concentration level may have adequately affected synthesis of chlorophyll pigment complex that led to reduced chlorophyll content. As the EM concentration level fell to EM 200g/L to EM 50g/L, the plants may have lost nutrients as well as turgor with relative EM concentration level reaching lowest values when all the plant available nutrients had been used up. Intensification of nutrients stress due to reduced microbial load led to reduced leaf yield, possibly due to reduction in leaf components such as leaf number, leaf fresh weight and leaf area.

Effect of EM on percentage spider plant leaf Water Content

Leaf relative water content significantly decreased (*P≤0.05*) with reducing EM concentration level. This finding is in agreement with that of [22] who established that relative water content of eggplant decreased with reduction in moisture level and microbial load in the soil. In their study, they observed that leaf relative water content ranged from 88.4% in soil enriched microbial load plants to 43.8% in microbial stressed eggplants. A study also found similar results in soybean leaves [17]. Leaf relative water content varied with spider plant varieties and moisture levels. This denotes different adaptability to EM concentration level among spider plant accession. The EM could have played a major role towards improving water content of the soil, due to improved water holding capacity of the soil especially at EM 200g/L level, which recorded the highest water content. The interaction between the spider plant varieties and EM concentration level was significant. The higher relative water content reported for most farmers' accessions compared to exotic variety (MSL-17) may be attributed to the genetic make-up due to the fact that farmers' varieties have not yet undergone selection pressure that may lead to loss of traits for EM presence adaptability. A study [7] reported similar findings in spider plant genotypes and a commercial variety (saga). Reduction of leaf relative water content with EM intensification is aimed at increasing the sap concentration of the leaf that result in increased osmotic pressure [20].

Effect of EM on percentage spider plant Leaf Yield

Increase in EM concentration level significantly increased (*P≤0.05*) leaf yield by 25.7% and 14.0%, in exotic and local varieties respectively. The reduced leaf yield may be attributed to the negative effect of EM concentration level on breakdown of organic material in order to boost nutrient content of the soil by EM, leading to reduction in photosynthetic rate and carbon assimilates in plants and consequently less biomass produced [1]. Leaf number, size and weight are the first parameters to be affected when the plant faces any nutrients level stress [3]. Similar results have been reported in groundnut (*Arachis hypogea* L.) (3), peanuts [2] and amaranth [4]. The interaction between the spider plant accessions and EM concentration level was significant. This variation demonstrates huge variability among spider plant varieties in adaptability to EM concentration level.

Exotic variety (MSL-F170 recorded significantly (*P≤0.05*) better performance in number of primary branches per plant, number of leaves per plant, number of days to flowering, and leaf yield per plant than local variety (MSL-F3) under EM concentration levels. This points to the existence of desirable agronomic traits that can be harnessed in breeding programmes for developing high performing spider plant varieties for use under EM enriched soils. The variety could be recommended for farmers' cultivation.

IV. Conclusion and Recommendations

Increased level of EM concentration at 200g/L significantly increased (*P≤0.05*) plant height, number of leaves per plant, single leaf area, chlorophyll content, leaf relative water content, and leaf yield. Results indicate that there exist significant genotypic differences in adaptation to EM concentration levels among the evaluated spider plant genotypes.

Spider plant varieties varied significantly (*P≤0.05*) in agronomic traits, with variety MSL-17 (exotic) at EM 200g/l, recording superior agronomic traits for growth (plant height, leaf number, leaf size, chlorophyl content) and yield components (weight and water content) in the greenhouse experiment, hence may be used for production and in the development of improved spider plants.

The interaction between spider plant varieties and the source was significant. The significant variation in quantitative traits observed among the varieties from the two sources presents great possibility for the development of suitable varieties as seed source.

The responses to EM concentration level in most of the physiological, growth and yield parameters varied in their response to EM concentration with the varieties. Further, variety MSLF-17 (exotic), expressed superior adaptability to EM concentration level compared to MSL-F3 (local). This points to the existence of exploitable EM concentration level adaptation and tolerance genes in spider plant varieties that can be utilized in breeding programs for EM adaptability.

Variety that expressed superior adaptability to EM concentration levels MSL-F17 is recommended for adoption by small scale farmers for direct production.

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COMPETING INTERESTS
Authors have declared that there are no existing competing interests.

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