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RESEARCH ARTICLE

CULTIVAR-SPECIFIC GROWTH AND YIELD OF MUKUNUWENNA (*Alternanthera sessilis*) IN THE LOW COUNTRY WET ZONE, SRI LANKA.

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ABSTRACT

Joyweed/*Mukunuwenna* (*Alternanthera sessile*) is a globally significant leafy vegetable, yet its maximum yield potential remains largely unrealized due to the limited genetic diversity of existing varieties. Farmers frequently lack precise knowledge about the yield potential, growth characteristics, and quality of the produce. Few attempts of research attentions were given to assess its growth characteristics, susceptibility to diseases and pests, consumer acceptability, and yield potential. Therefore, this study aims to comprehensively evaluate growth and yield traits, sensory qualities and morphological features of eight carefully selected *Mukunuwenna* cultivars. Thus, identifying the most suitable *Mukunuwenna* cultivars for the Low Country Wet Zone, Sri Lanka. In this investigation, we assessed four *Mukunuwenna* selections, including one wild (red) variety, alongside three local *Mukunuwenna* cultivars, focusing on their growth, yield and morphological characteristics under upland field conditions at the Agriculture Research Station, Thelijjawila, Sri Lanka. The study followed a randomized complete block design (RCBD) with three replicates. Data were meticulously collected for eight growth parameters and two yield parameters including average internodal distance, average leaf length, average leaf width, average number of shoots per unit area, average number of leaves per stem, average number of flowers per stem, average shoot height, average chlorophyll content, average leaf to stem ratio, and average yield per plot. The results, analyzed through ANOVA and mean separation demonstrated significant differences ($P< 0.05$) among Mukunuwenna cultivars across various attributes, To assess the diversity in growth and yield, a principle component analysis was conducted. A sensory evaluation was performed to assess the consumer preference. Notably, the Piliyandala selection exhibited the most promising growth and yield traits, particularly excelling leaf to stem ratio and gaining the highest consumer preference. Other notable performers were the Colombo selection, *Weda Mukunuwenna* and Cultivar M7 showing preferable growth and yield traits with strong consumer appeal. Considering these findings, we conclude that Piliyandala selection, Colombo selection, and Cultivar M7 exhibit preferable growth and yield traits for commercial cultivation, while *Weda Mukunuwenna* stands out as an ideal choice for home garden cultivation under upland conditions in the Low Country Wet Zone, following recommended agronomic practices. This study's outcomes hold significant promise for further research endeavors, focusing on enhancing desirable growth and yield traits.

Keywords: *Alternanthera sessilis,* Growth parameters, Quality, Wet zone, Yield performance

INTRODUCTION

Alternanthera sessilis, which is having several spreading branches that bear short petiolate, simple leaves and small white flowers and usually appeared as a small prostrate herb (Gupta *et al.* 2012) . Leaves are usually between 0.6 and 5 cm in length, between 0.3 and 1 cm in width, simple or lanceolate in shape, opposite in leaf arrangement and having short petiole or sessile. Leaf apex is acute – blunt and is attenuated at the base. Inflorescences are sessile, silvery-white clusters which are densely packed into spikes of 1.5 to 2.5 mm long (Sravani *et al.* 2017). *Alternanthera sessilis* can grow in various

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climatic conditions and it can survive in number of environmental conditions. A warm climate, bright sunlight and an appropriate level of humidity are the optimum growing conditions (Shehzad *et al.* 2018). Although plants having abilities to tolerate extremely dry conditions, *Alternanthera sessilis* prefers habitats which receive higher humidity conditions constantly that are perfect for growth. The natural propagation of the plant can happen through seeds, via wind-and water -dispersed. But especially and most commonly through rooting at stem nodes (Thomas *et al*. 2014).

Green leafy vegetables hold a significant place in Sri Lankan diets, primarily due to their affordability, widespread availability, and rich nutritional content, including essential vitamins, minerals and fiber. Among these leafy vegetables, *Mukunuwenna* stands out as the most commonly consumed leafy vegetable (Kanake *et al.* 2016). Especially, *Alternanthera sessilis* contained higher protein, fat, and carbohydrate contents than other leafy vegetable species (Nadeeshani *et al.* 2018). According to Shehzad *et al.* (2018), *Alternanthera sessilis* contain water (80 g/100 g), energy (251 kJ/mol), protein (4.7 g/100 g), fat (0.8 g/100 g) and carbohydrate(11.8 g/100 g), starch (3.2 g/100 g), amino acid (0.225 mg/100 g), vitamin B1(2.76 mg/100 g), vitamin B2(12.6 mg/100 g), fiber (2.1 mg/100 g), calcium (148 mg/100 g) and phosphorus (45 mg/100 g). It often accompanies traditional rice and curry dishes in most households, cherished for its distinctive flavor and cost-effectiveness (Balasuriya and Dharmaratne, 2007). *Alternanthera sessilis* has been used for medicinal and curative purposes in many Asian and African countries in the world (Abbas *et al.* 2022). According to Shehzad *et al.* (2018), *Mukunuwenna* is having anti-fungal, anti-oxidant, anti-cancer, anti-diabetic, anti-microbial, anti-pyretic, anti-inflammatory, anti-ulcer, anti-diarrhoeal, anti-bacterial, anti-malarial potentials. As a result, this particular herb is used in many herbal preparations in Siddha Vaidya and Ayurvedic medicine industry.

While various types of *Mukunuwenna* thrive in different regions of the country, farmers often lack precise knowledge about their yield potential, growth characteristics and produce quality. Consequently, They sometimes cultivate mixtures of different *Mukunuwenna* types and cultivars, resulting in suboptimal yields for their specific agro-ecological zones (Wahundeniya, 1999). Moreover, this particular leafy vegetable has not received adequate research attention in Sri Lanka with only limited efforts made to evaluate its growth parameters, pest and disease susceptibility, consumer acceptance and yield potential. The scarcity of pure Mukunuwenna varieties further complicates matters, emphasizing the necessity for the evaluation and identification of local available *Alternanthera sessilis* (*Mukunuwenna*) pure lines. This initiative aims to promote underutilized cultivars among farmers, as a valuable resource for human consumption, medicinal purposes, and landscaping.

Germplasm collection serves as a pivotal and beneficial undertaking, allowing for the study of phenotypic and genetic variation among varieties of a crop species. This process aligns with the goal of enhancing crop improvements in plant breeding, aiming to develop plants with increased yields, improved quality disease resistance, and tolerance to adverse environmental conditions (Mohammed *et al*. 2022).There have been attempts to gather Mukunuwenna germplasm from various sites and investigate its growth, yield, and quality characteristics. Morphological characteristics were used to identify 19 Mukunuwenna selections. Only two of these Mukunuwenna selections were determined to be promising due to their high yield potential or good quality characters; of these, "Piliyandala" was suggested by the Department of Agriculture in Sri Lanka in 1999 and has since gained popularity among Sri Lankan farmers. Wide variations in the Mukunuwenna grown by Sri Lankan farmers have been noted in this study. The leaf characters show that the selections could be grouped into eleven groups, indicating a very high variability within the Mukunuwenna germplasm Wahundeniya (2007). Thus, this study was undertaken to comprehensively

assess and compare the growth and yield parameters of *Mukunuwenna* cultivars in Sri Lanka focusing on the unique climatic conditions of low country wet-zone and to select best performing cultivars and selection to be cultivated in farmer fields best on the results.

MATERIALS AND METHODS

The experiment was conducted at the Agriculture Research Station, Thelijjawila located in the Matara district of the Southern Province, which belongs to Low Country Wet Zone, Sri Lanka. The growing period was from July 2022 to September 2022. Eight *Mukunuwenna* cultivars were utilized in this study. Among these, four were selections obtained from the Agricultural Research Station, Thelijjawila, Department of Agriculture (DOA): Piliyandala selection (M1), Colombo selection (M2), Weda Mukunuwenna (M3), Maswanna selection (M4). Additionally, a wild variety (red variety -M5) was included, along with three cultivars (M6, M7, M8) sourced from farmer fields nearby (Figure 1). Ten cm length cuttings which were taken excluding the tip area, treated with Captan fungicide, and planted on the beds, with one cutting per hill, resulting in 56 cuttings per plot and a spacing of 20cm x 10cm. All other cultural practices, such as weeding, earthing up, and irrigation were executed as per the crop's specific requirements, adhering to the recommendations of DOA, Sri Lanka.

The experimental site featured relatively a flat terrain having a slight downward gradient, which had remained fallow during the previous season, with no prior cultivation of *Mukunuwenna.* Three blocks were arranged perpendicularly to the gradient. Each plot was an experimental unit, which measured 2 meters in length and 1 meter in width, separated by 0.3 m wide alleys. To prepare the beds, four kilograms of organic manure were incorporated into each plot two weeks before planting. Three days prior to planting, inorganic fertilizer was applied in accordance with Department of Agriculture (DOA)

Figure 1: Morphology of the selections and the cultivars used where, (a)- Piliyandala selection (M1), (b)-Colombo selection(M2), (c)-Weda Mukunuwenna(M3), (d)-Maswanna selection (M4), (e)- Red selection(M5), (f)-Cultivar M6, (g)-Cultivar M7, (h)-Cultivar M8.

recommendations. The basal dressing, following DOA guidelines, included 9 kg of Urea, 13.5 kg TSP and 10 kg MOP. Treatments were arranged in a randomized complete block design (RCBD) with three replicates. Experiment was conducted under irrigated conditions. Collection of weather data was done daily at the research station premises.

Data collection involved randomly selecting 20 grids (each grid measuring 15cm^2) within a frame containing 60 grids, excluding the boarder effect. The following parameters were measured: the number of shoots per grid, internodal distance (cm), leaf length (cm) and width (cm), average shoot height (cm), SPAD value for chlorophyll content (%), number of leaves and flowers per stem, leaf and stem weights (g), yield per plot (g). A sensory evaluation of *Mukunuwenna Sambal* was conducted to determine consumer preferences for the *Mukunuwenna* cultivars used in the experiment .The sensory evaluation encompassed three sensory properties, appearance, smell and taste. A 500 g sample of the edible portion of *Mukunuwenna* from each cultivar was used. These samples were cut, mixed with equal amounts of coconut scraping, onion, green chilli, turmeric powder, and salt and cooked for two minutes. Parameters such as appearance, taste and smell were assessed by each panelist. The sensory evaluation evolved. Thirty semi-trained panelists were used, and observations and comments were recorded using a five-point hedonic scale (5=extremely like, 4=like, using 3=normal, 2=dislike, 1=extremely dislike).

Statistical analyses included ANOVA performed for growth and yield data using SAS software followed by mean separation using the Duncan Multiple Range Test (DMRT). Sensory data analysis using the Freidman test in Minitab 17, and principal component analysis using the SPSS statistical tool. The final selections of the most suitable cultivar or the selection were done based on the combined evaluation of yield performance, growth performance and consumer preference.

RESULTS AND DISCUSSION

The study revealed substantial variation in growth characteristics and yield traits among the eight selected *Mukunuwenna* cultivars under average temperature 25^{0}C to 30.3^{0}C and rainfall of maximum 55.3 mm.

Variation of Growth Characteristics

The primary growth parameters that are frequently used in plant investigations particularly in leafy vegetables are height, leaf area, volume, and biomass (Hu *et al.* 2018). The number of shoots (ANS) in 15 cm^2 exhibited significant variations (Table 1). Notably, Piliyandala Selection (M1), Colombo (M2), Red Variety (M5) and M7 Cultivar recorded significantly higher shoot numbers, suggesting more vigorous growth and potentially higher yields. Conversely, *Weda Mukunuwenna* (M3), *Maswanna* Selection (M4) and M6 Cultivar displayed the lowest shoot numbers. Internodal length(AID) serves as an indicator of leafiness, with lower AID values indicating greater leaf density. Significant differences in AID were observed with *Maswanna* (M4) exhibiting significantly higher values. Consequently, Piliyandala (M1), Colombo (M2), *Weda* (M3) and Cultivar M6 displayed lower AID values (Table 1). *Maswanna* (M4) stood out with the statistically highest mean plant height (34.3) at the harvesting stage followed by the Red variety (M5) with a significantly higher shoot height (29.1) recorded after the *Maswanna* selection. In contrast, Cultivar M6 and Colombo selection (M2) had the shortest shoots, with mean heights of 15.81 coupled with shorter internodal distances. No significant difference was observed in the means of average shoot heights among Piliyandala (M1), *Weda* (M3), Cultivar M7 and M8 Cultivar (19.94, 19.73, 20.56 and 19.94, respectively).

Since the main purpose of leafy vegetables is to produce fresh leaves, the number of leaves per plant along with leaf size determine the overall yield (Bhavithra *et al.* 2019). Leaf size affects leaf yield in these crops and it is a parameter that should be measured precisely in leafy vegetables (Nakanwagi *et al.* 2018). *Maswanna* (M4) recorded significantly higher

average leaf length (ALL) and width (ALW) (Table 1), reflecting longer internodes, and broader leaves, indicating the species' capacity for cell elongation. Conversely, Cultivar M6 exhibited the smallest leaves but surprisingly has the highest number of leaves per stem (NLS) 45 days after field planting of ten centimeter stem cuttings. The lowest NLS was recorded in Cultivar M7. Number of flowers (NFS) at the harvesting stage significantly varied among the varieties, with higher NFS considered a disadvantage for a leafy vegetable, as it can diminish flavour. Therefore, varieties with significantly lower NFS such as *Weda* (M3), *Maswanna*(M4), Cultivar M7 and Cultivar M8, appear more suitable for commercial cultivation.

In most plants, leaves make up the majority of the entire canopy surface. They serve as the primary location for physiological functions like transpiration and photosynthesis. They host a variety of metabolic processes and control gas exchange, both of which have an impact on crop yield and growth (Nakanwagi *et al.* 2018). Chlorophyll content (CHO) is indicative of a plant's photosynthetic ability, which in turn influences growth rate and yield. Colombo selection recorded significantly higher CHO (%) than the other species, with a mean value of 57.38. In contrast, the Red variety (M5) had significantly lower CHO (36.56) although it displayed no significant difference with *Maswanna* selection (Table 1). It is possible that the Red variety contains other pigments that can efficiently absorb light, potentially contributing to its higher growth rates.

Variation of Yield Characteristics

Average economic yield per plant (AY) significant differed among the selected cultivars (Table 1). The Red Variety (M5) recorded the significantly highest mean AY (4.84 kg/harvest/plot), while Cultivar M6 had the lowest AY (1.36 kg/harvest/plot). Leafiness is an essential factor for consumers when purchasing leafy vegetables. Piliyandala selection recorded significantly higher leafiness, with mean value of 2.0 for average leaf to stem ratio (LSR). Colombo selection (M2) also exhibited substantial leafiness, as reflected in the LSR. However, while Red Variety and *Maswanna* selection achieved high AY, they had lower leafiness and higher stem weights. The *Maswanna* variety despite its larger leaves, had longer AIDs, resulting in lower leafiness. A similar study has conducted to compared the growth and yield performance of four different accessions; Colombo, Erawwawala, Selection 1 and Selection 2 to the suggested Piliyandala variety, demonstrated noticeably high yields in Piliyandala, Colombo selection,

Table 1: Growth and yield characteristics of selected Mukunuwenna selections/ cultivars.

Parameters	Mukunuwenna Species							
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
ANS	20.4^{ab}	23.6^{a}	15.2^{cd}	12.6^{d}	22.3^{a}	15.4^{cd}	22.4^{a}	18.1^{bc}
AID	3.76^{bcd}	3.5^{cd}	3.92^{bcd}	8.13^{a}	5.02^{b}	2.96^{d}	4.44^{bc}	5.00^{b}
ASH	19.9^{c}	18.0^{cd}	19.7^{c}	34.3^{a}	29.1^{b}	15.8^{d}	20.6^{c}	19.9^{c}
ALL	3.0^{c}	2.9^{c}	3.9^{b}	6.0^{a}	3.7^{b}	2.4^{d}	3.6^{b}	2.9^{c}
ALW	1.35^{b}	1.16^{c}	0.69^{d}	2.64^{a}	1.32^{b}	0.60^{d}	1.21^{bc}	1.14^{c}
NLS	11.98^{d}	12.69^{cd}	13.66^{bc}	12.65^{cd}	14.80^{b}	19.7^{a}	9.54^{e}	11.43^{d}
NFS	12.52^{a}	8.76^{b}	4.53^{d}	5.08^{d}	11.97^{a}	7.31^{c}	5.07^{d}	4.07^{d}
CHO	49.66^{bc}	57.38^{a}	48.12^{c}	37.13^{d}	36.5^{d}	54.23^{ab}	54.16^{ab}	50.96^{bc}
AY	1.93^{cd}	1.86^{cd}	1.62^{de}	2.81^{b}	4.84^{a}	1.36^{e}	2.34^{c}	2.26^{c}
LSR	2.00^{a}	1.00^{b}	0.67^{bc}	0.50^{bc}	0.40^{c}	0.33^{c}	0.29^{c}	0.25^{c}

Note: Means denoted by a different letter indicate significant differences between treatments ($p < 0.05$). ANS – Average number of shoots/grid, AID- Average internodal distance (cm), ASH-Average shoot height (cm), ALL- Average leaf length (cm), ALW- Average leaf width (cm), NLS- Average number of leaves per stem, NFS- Average number of flowers per stem, CHO- Average chlorophyll content (%), AY-Average yeild/plot/harvest (kg), LSR – Average leaf:stem.

Erawwawala selection and selection 1. But no appreciable differences in the leaf to stem ratio have recorded between the accessions in this study (Siriwardhana *et al*. 2012).

Principle Component Analysis

The most critical growth and yield traits were considered for selection based on the principle component analysis (Table 2). The first principle component (PC1) described (51.509%) of the total variance and was associated with average height (0.988), number of flowers (0.901), leaf width (0.901), leaf length (0.885) internodal distance (0.878), leaf: stem ratio (0.795), and average yield (0.633), PC2 accounted for 23.045% of the variance and was primarily associated with the number of flowers (0.909) and the number of shoots per unit area (0.889), PC3 which accounted for 13.345% of the variance, was influenced by the number of leaves per stem (0.940) (Table 2). The most important growth & yield characters which were explained according to the principle component analysis were considered for selecting suitable *Mukunuwenna* species for the low country wet zone. Finally, the preferred species were selected considering the consumer preference of the sensory evaluation.

Table 2: Principal Component for growth and yield parameters of evaluated eight Mukunuwenna selections/cultivars.

Parameter	1	2	3
ANS	-.187	**.889**	-.389
AID	**.878**	-.305	-.201
ALL	**.885**	-.354	-.057
ALW	**.901**	-.113	-.281
NFS	**.901**	**.909**	.093
NLS	-.213	-.020	**.940**
ASH	**.988**	-.013	.112
LSR	**.795**	.091	.186
YD	**.633**	.091	.093
CHO	-.812	-.283	-.336

Note: Means denoted by a different letter indicate significant differences between treatments ($p < 0.05$). ANS – Average number of shoots/grid, AID- Average internodal distance (cm), ASH-Average shoot height (cm), ALL- Average leaf length (cm), ALW- Average leaf width (cm), NLS- Average number of leaves per stem, NFS- Average number of flowers per stem, CHO - Average chlorophyll content (%), AY-Average yeild/ plot/harvest (kg), LSR – Average leaf:stem

Sensory Evaluation

Sensory evaluation revealed that Piliyandala selection exhibited the best sensory properties in all three parameters: appearance, smell and taste. Panelists overwhelmingly preferred *Mukunuwenna sambal* made from Piliyandala selection while the *Maswanna* selection was the least favored for consumption among the cultivars. Despite being a wild variety, the Red variety (M5) displayed favorable smell and taste. *Weda Mukunuwenna* also had a better taste than other cultivars, ranking next to Piliyandala, and achieved a medium preference for appearance and smell (Figure 2). Consumers generally prefer mukunuwenna with more leaves and less stems. Therefore, selecting varieities/selections with higher leaf: stem ratio will be an advantage to the farmer. This study addressed only the preference after cooking. Therefore, assessing the consumer buying behavior would be another option.

The trial experienced heavy rains during the late stages of the growth. The white rust disease to green foliage was a major problem experienced as a result of the prevailing weather conditions.

The results relate to the *Mukunuwenna* cultivation under upland conditions with raised beds. The same experiment can be

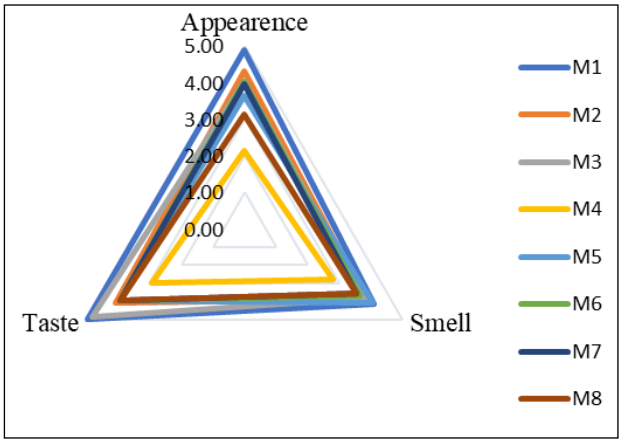

Figure 2: Sensory profile of the prepared *Mukunuwenna* sambal from eight selected selections/ cultivars.

launched to address the performance of same selected species under low land conditions or upland conditions with sunken beds. Assessing disease severity, susceptibly and resistance among the *Mukunuwenna* germplasms also important when recommending a selection for a particular agro ecological region. Since this crop cannot be hybridized, the only method to produce high-quality varieties is to choose varieties from the germplasm that is readily available in the area. Apart from the primary goal of assessing growth and yield performance and quality, another goal of this study was to locate, describe, and preserve the local *Mukunuwenna* germplasm in a field gene bank.

CONCLUSION

In summary, the Red variety demonstrated the highest yield potential, yet suffered from poor consumer preference. Conversely, despite M4 (*Maswanna selection*) yielding well with large-sized leaves, it failed garner consumer flavour. The M6 cultivar yielded the least under upland conditions, and its unpopularity among both farmers and consumers was eident. Colombo selection emerged as the preferred choice due to its favorable growth and yield traits, coupled higher consumer preference. Piliyandala selection, while achieving a comparatively higher yield, notably excelled in leafiness and recorded the highest consumer preference. *Weda Mukunuwenna* exhibited a higher consumer preference and is recommended as a quality selection for home gardens. The M7 cultivar displayed preferable growth and yield traits, along with good consumer preference. In contrast, Cultivar M8, with lower leafiness and higher stem weight, faced limited consumer preference. Considering the combined factors of growth and yield traits and consumer preference, it can be concluded that Piliyandala selection, Colombo selection and Cultivar M7 exhibit preferable characteristics for commercial cultivation while *Weda Mukunuwenna* is well suited for home gardens under upland conditions in the Low Country Wet Zone with recommended agronomic practices. The study's findings provide valuable insights for further research aimed at enhancing desirable selections with improved growth and yield traits in the low country wet zone of Sri Lanka. Additionally, the study's applicability extends to research comparing yield performances under lowland conditions within the agro-ecological regions.

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AUTHOR CONTRIBUTION

HAPAS and DLW designed and supervised the study, UMURA perform the experiments, analyzed the data, and wrote the manuscript. All authors discussed the results and commented on the manuscript.

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