WWJMRD 2022; 8(03): 1-6
www.wwjmrd.com
International Journal
Peer Reviewed Journal
Refereed Journal
Indexed Journal
Impact Factor SJIF 2017: 5.182 2018: 5.51, (ISI) 2020-2021: 1.361
E-ISSN: 2454-6615
DOI: 10.17605/OSF.IO/K6V8H

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Morphological Evaluation of mulberry genotypes across different agro-ecological conditions in Uganda

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Abstract
Mulberry (Morus spp.) is the chief source of food for the silkworm (*Bombyx mori L.*) which grows in diverse climatic conditions and is regarded as a unique plant on this earth due to its ability to be cultivated in different forms; multiple uses of leaf foliage and its positive impact in environment, bioremediation of polluted sites, conservation of water, prevention of soil erosion and improvement of air quality by carbon sequestering and pharmaceutical, food, cosmetic and health care industries has gained the attention of industrialists. Eight different mulberry genotypes were evaluated using eleven different traits related to agronomic and quality attributes as a feed for silkworm. The experiments were conducted in nine different districts across Uganda using a randomized complete block design. Analysis of variance was performed on quantitative characters to assess the morphological diversity. The results obtained revealed a high significant difference among the genotypes across all the locations. The traits that were significantly different across the mulberry accessions included lamina width and petiole length ($P \leq 0.01$), petiole width and growth height ($P \leq 0.05$), internodes distance and number of branches ($P \leq 0.001$). Mysore Local and Thailand varieties had the highest plant height, Kanva2 had the highest number of branches, the longest bud length was observed in Local variety while the leaf yield was more in Thailand. The correlation coefficient showed a positive significant association of all the traits with leaf yield. The results obtained indicated that genotypes performed slightly differently in differently locations due to different factors studied. Overall, we therefore recommend farmers in these diverse ecological zones to grow these mulberry varieties, with good agronomic practices such as proper spacing, timely weeding and pest and disease management in order to obtain consistent high yields.

Keywords: Correlation coefficient, Genetic diversity, Mulberry, traits, Uganda.

Introduction

Mulberry (*Morus spp*.), the unique food source of domesticated silkworm (Bombyx mori L.), is a perennial plant propagated exclusively through stem cuttings (clones) and thus the acquired true-to-type plant population. The *morus spp* is a widely distributed crop in the temperate, sub-tropical and the tropical regions of the world and is highly adaptable to a wide range of climatic, topographical and soil conditions (Hoseini et al., 2018). Though it is believed that this species originated from the lower slopes of Himalayas in China and India, its current distribution across the regions reflects particularly its adaptability to a wide range of environmental conditions (Tikar and Vijayan., 2010). Plant species with a wide range of environmental adaptations often exhibit numerous morphological and physiological characteristics (Cordell et al., 1998) and this morphological variability in mulberry is believed to have contributed to its growth and survival under disruptive environmental conditions across the world (Gray, 1990). History states that this plant has been used in sericulture industry throughout the world (Natic et al., 2015). In recent years, mulberry-based sericulture has been increasing in Rwanda, Kenya, Uganda and other East African countries.

Although mulberry has been in cultivation for centuries in different parts of the world, identification of the best performing varieties in Uganda is necessary. Proper and appropriate selection of the tropical cultivars based on the morphological characteristics/suitability is a necessity in availing reliable genetic resources for the farmers. This is because leaf is the economic product in mulberry cultivation unlike other agricultural crops. Mulberry leaf contributes 38.2% towards the production of a successful cocoon crop (Boraiah 1986).

Furthermore, Selection of suitable genotypes from gene pool therefore requires a thorough knowledge of morphological characteristics of different genotypes for farmer utilization (Yilmaz et al., 2012). Traditional methods for cultivar identification are based on the observation of phenotypic characteristics as they aid fast and simple evaluation of variability and; hence, are considered as an effective means of preliminary evaluation of assessing genetic diversity among morphologically distinguishable accessions (Cˇolic´ et al., 2012). Furthermore, morphological characterization is the official method accepted for registration and protection of new cultivars (Ertan, 2007). Therefore, the main objective of this study was to assess the morphological and genetic variability of the mulberry cultivars available in Uganda and for sericulture use.

2. Materials and Methods

Eight mulberry genotypes (All foreign accessions as shown in Table 1) were evaluated in seven locations and different seasons. The locations were; Sheema, Mubende, Nakaseke, Bulambuli, Pallisa, Bukedea, Iganga, Bulambuli 2 and Zombo. These are located in eastern, north eastern and north western Uganda during 2019-2020. These locations represent the potential areas for sericulture in Uganda and are characterised by arid and semi-arid conditions. All the genotypes used in the study were obtained from China, India and Kenya (Table 1). In all locations, genotypes were planted in 4.0 m × 5.0 m plots at a spacing of 1.0 M × 1.0 M laid out in a Randomised Complete Block Design (RCBD) with each genotype replicated three times. Throughout the experimental period, the plots were kept free of weed by hoeing. No Fertilizers or supplementary water through irrigation was applied during the trials. Major pests and diseases (Leaf spot, leaf rust and powdery mildew) were controlled by 1-2 sprays (depending on pest pressure) using Dimethoate 40%EC and Rocket 44 EC (Profenofos 40% + Cypermethrin 4%) at recommended rates.

After one year of establishment in the field, data was recorded by following a 5-crop schedule. Data from the 5 plants were recorded on various yield attributing traits such as number of tillers (NT); plant height (HT), total shoot length (TSL), nodal distance (ND), number of branches per plant, weight of 100 leaves, leaf area, leaf yield/plant and leaf yield (LY) were recorded. These measurements used were adopted from Adolkar et al. (2007) and Food and Agriculture organization (FAO), (2007).

A combined analysis of variance to assess the significance of genotype × environment interactions was carried out using R version 4.0.1 (R Core Team, 2014). The mean values for all the agronomic traits were later used for correlation matrix

Table 1: Different mulberry varieties and their origin.

S.NO	Genotype	Species	Country of origin
1	Thika	M. alba L.	Kenya
2	Kanva2	M. indica L.	India
3	Embu	M. alba L.	Kenya
4	Thailand	M. alba L.	Thailand
5	Chinese	M. alba L.	China
6	Mysore Local	M. indica L.	India
7	S.36	M. indica L.	India
8	S.54	M. indica L.	India

Adopted from Vijayan et al., 2003 and Wangari Peris and Ngode Lucas (2016).

3. Results and Discussion

3.1 Effect of environment and genotypes on the growth characteristics of different mulberry varieties under study

Morphological analysis is considered as a first approach towards the assessment of genetic diversity in a plant species (Boubaya et al., 2009). In this study, an experiment was conducted to evaluate the agronomic performance of different mulberry accessions across different locations in Uganda and to understand their genetic variability. The results presented in Table 2 show the effect of environment and genotypes on the growth characteristics of different mulberry varieties in different districts in Uganda. It is evident from the morphological traits and the regions of cultivation that the varieties used in this study showed considerable variations across the different agro-ecological zones in Uganda. Analysis of variance showed a significant variation between the genotypes × location ($P<0.05$). There was also significant variation among the parameters in all genotypes across all the agro-climatic regions except for the number of tillers which was not significant ($P=0.721$).

Means of different parameters across genotypes revealed that plant height, lamina length, lamina width, internode distance, number of branches, petiole length and bud length varied significantly ($p \leq 0.05$) within the accessions while the number of tillers was not statistically significant in all the accessions. Thailand, S-36, Embu and Local variety had the largest leaves while Chinese variety had the smallest leaves. Local, Thika and Thailand were the highest plant height among the accessions respectively whereas the shortest was Chinese. Peris et al (2013) studied the morphological variations in different accessions in two different locations in Kenya and the results obtained concur with the results in this study that location (environment) significantly influences the performance of mulberry.

Analysis of variance for genotype × location showed that this interaction had an influence on the morphological traits revealing that lamina length, lamina width, petiole length, plant height, bud length, leaf area, internode distance, total plant biomass, number of branches, 100 leaf weight and diseased leaves were highly different ($p \leq 0.05$) across the locations. On contrary, the number of tillers was not statistically significant across all the locations. Reaction to pests and diseases by all the genotypes across the locations was also highly significant

Table 2: Means of different phenotypic traits of 5 mulberry accessions evaluated across different environments in Uganda.

TRAITS	LOCATION									VARIETIES									se	cv (%)
	Sheema	Mubende	Nakaseke	Iganga	Bulambuli	Bulambuli 2	Bukedea	Pallisa	Zombo	S-36	S-54	THAILAND	KAMULI	KANVA-2	CHINESE	THIKA	LOCAL	EMBU		
bud length(mm)	4.685ab	4.123b	4.993a	4.236b	4.319b	4.194b	4.08b	4.993ab	4.583ab	4.24bc	4.734b	4.802ab	4.123bc	3.925cd	3.456c	4.555bc	5.39a	4.333bc	1.004	1.41
lamina length(cm)	19.45062ab	18.51728b	20.18472a	20.15972a	19.45278ab	19.55278ab	20.20972a	18.73472b	20.28750a	19.99753bc	20.17901bc	24.09136a	19.13951c	19.45926c	13.65185d	19.26790c	21.01605b	19.57222c	2.544	13.95
lamina width(cm)	14.716b	14.713b	15.538ab	15.879a	14.934ab	14.601b	15.802a	14.697b	15.458ab	16.92b	15.359cd	18.882a	14.698de	15.065cde	10.2407f	14.0407e	15.667cd	16.138bc	2.111	10.92
leaf area(sq.cm)	289.777b	287.659b	327.751a	327.845a	305.475ab	299.493ab	328.291a	299.493b	327.851a	341.641b	313.666bc	463.374a	286.86cd	296.099cd	151.8741e	274.6827d	334.397b	333.992b	10.76	14.39
petiole length(cm)	3.979cde	4.262bc	4.733a	4.105bcde	3.744e	4.105bcde	4.413ab	3.844de	4.206bcd	3.9209b	4.422a	4.717a	3.688b	3.7555b	3.725b	4.437a	4.429a	4.844a	0.848	9.79
internode distance(cm)	4.755bc	4.727bc	5.508a	4.608c	4.79bc	4.938bc	5.072b	4.537c	5.085b	4.864b	4.708b	5.196ab	4.903ab	4.987ab	3.8c	5.401a	5.183ab	5.127ab	0.981	10.27
plant height(cm)	209.6568 c	192.5741cd	286.3611 a	274.0069 a	160.8903 e	182.0958de	246.5694 b	163.5431 e	205.0958cd	199.021c	195.5370c	237.7654ab	214.0802bc	192.3840cd	168.3654d	244.7778a	257.0099a	194.0556cd	10.75	17.46
Total Plant biomass (Kg)	846.5062c	813.0247c	1700.1389a	1632.7639a	802.4722c	980.0139c	1311.5556b	716.75c	1548.125ab	1328.7284abc	1098.3951abc	1190.1235abc	1041.2346bc	1094.9136abc	617.0123d	1377.4691ab	1420.9753a	975.3333c	10.87	7.59
Leaf yield/plant (kg)	211.7351d	211.2109d	329.6364c	445.4028a	397.3611ab	415.6428ab	456.1903a	366.3333	457.9956a	404.7622b	385.2598b	467.2814a	363.679bc	368.2228bc	178.1672d	340.6088bc	394.256b	317.4356c	10.488	20.05
Number of branches	16.1a	9.17b	11.4b	6.09c	10.6b	4.4c	4.5c	4.6c	10.36b	7.8bcd	8.56bc	4d	12.703a	11.2ab	8.72bc	9.1bc	7.01cd	6.6d	7.062	4.53
number of tillers	1.92d	1.83d	1.77d	2.12cd	2.43bcd	2.52bcd	3.04ab	2.8abc	3.61a	2.38a	2.81a	1.9a	2.45a	2.58a	2.54a	2.58a	2.35a	2.27a	1.903	4.42
number of diseased leaves	57.8b	57.2b	117.2a	14.6c	5.62c	10.3c	8.48c	3.01c	7.05c	38.5ab	32.5ab	21.18c	29.7ab	25.1b	22.1c	35.91ab	47.5a	46.3a	1.29	5.26
number of leaves destroyed by pests	26.19b	26.1b	68.12a	5.27c	7.22c	7.22c	7.875c	8.12c	7.97c	24.1a	19.7ab	14.02ab	16.8ab	16.6ab	8.85b	22.3a	21.8a	24.8a	1.136	5.553

Means in the same row having different letters are not significantly different at α=0.01 level of significance according to the Duncan's Multiple Range Test (DMRT).

3.2 Correlation coefficient matrix

The association of different agronomical traits were analysed through Pearson simple correlation matrix. Correlation coefficient analysis was used to depict the degree and extent of relationship among important plant traits being the main basis for crop selection. The results in this study revealed that different traits were associated directly or indirectly with each other.

Phenotypic correlation coefficient was highly significant for all the important characters like yield and yield related characters (Table 3). Lamina length showed significant positive correlation with lamina width. Leaf area positively correlated with both lamina length and lamina width. Number of branches per plant, number of seeds per pod, pod length and test weight exhibited positive and significant association with seed yield per plant. Bud length expressed positive significant correlation with laminar length, lamina width and leaf area. Petiole length showed significant positive correlation with laminar length, lamina width, leaf area and bud length. Internode distance showed significant positive correlation with lamina width, leaf area, bud length and petiole length but non-significantly correlated with lamina length. Number of branches per plant showed a negative significant correlation with lamina length, lamina width, and leaf area and showed a positive significant correlation with bud length. Number of tillers per plant revealed a negative insignificant association with all the traits. Plant height expressed positive significant association with lamina length, lamina width, leaf area, bud length and internode distance while petiole length and number of branches were positively correlated though not significant. Plant height was negatively correlated with the number of tillers. The 100-leaf weight exhibited positive and significant correlation with lamina length, lamina width, leaf area, petiole length, internode distance and plant height while it had a negative association with bud length and the number of branches. Number of diseased leaves expressed a positive significant association with bud length, petiole length, internode distance, number of branches and plant height but lamina length, lamina width, leaf area positively correlated though not significant while number of tillers negatively correlated. Number of leaves destroyed by pests showed positive significant association with lamina width, leaf area, bud length, number of branches, plant height and internode distance while lamina length and number of diseased leaves were positively correlated though not significant. Leaf yield expressed positive significant association with all the traits under study namely lamina length, lamina width, number of primary branches per plant, plant height, total shoot length, internodal distance and single leaf weight. Other traits are associated with each other and formed a complex relationship among them.

Mulberry is one of the most important commercial crops grown extensively as sole food plant for silkworm (*Bombyx mori*). Mulberry (*Morus* spp.) is a perennial and high biomass producing plant which also plays an important role in keeping the mother nature under constant phase by reducing the global warming through uptake of carbon dioxide from atmosphere and in return produce and release oxygen into the environment; which purifies the air and provide life to animals and other organisms (Rohela et al., 2020). Katul and Novick, 2009 stated that mulberry plants also contribute to soil health; retains water in soil sub-surface and cools overheated urban areas through its evapotranspiration mechanism of water cycle. It continues to be grown throughout the year in tropical and sub-tropical regions of the world (Vijayan et al., 2004). A large number of mulberry varieties are grown in several geographical regions of the world both for their edible fruit and for the silk industry.

The results in this study showed significant differences among the mulberry genotypes for some morphological traits studied. The study further revealed that the interaction between varieties and environment was slightly significant suggesting that each of these varieties can perform relatively the same way regardless of the growing environment/location. However, in these nine environments, the results for morphological traits showed better performance at Zombo station compared to other stations. This can be attributed to the differences in terms of soil type, rainfall patterns, temperatures, humidity and other important aspects that affect plant growth and yield in Uganda. The results were in agreement with Chambel et al. (2004) who stated that the environmental changes are not only responsible for changing the population phenotypic structure based on its genetic makeup to survive in the new environment and the level of each individual to alter its phenotype according to its environment. Not only does phenotypic plasticity make a genotype behave differently in different environments but also similarly in a particular environment (Bradshaw, 1965*)*. Several authors (Peris et al., 2013, Gray, 1990, Karst and Lechowics (2007) reported different modifications in mulberry as a means for adaptation to environment. Leaf variations in size, stomatal size and leaf polymorphism were as a result of phenotypic plasticity (Kitajima et al., 1997).

Yield-wise, no single variety was consistently superior in terms of agronomic performance across all the agro-ecological zones as performance varied in different locations. The above observation therefore gave a clear impression that yield traits in mulberry were variable and their response was not only dependent on genetic influence but also on the environment. In the combined analysis, Thailand variety exhibited the largest leaf sizes, short internode distance and fairly high branching attributes in all environments, thereby having the best traits that contributed to higher leaf yields compared to other varieties studied. These slight variations in performance observed amongst these genotypes may have been due to differences in genetic characteristics and environmental adaptations of the individual genotypes, which influence their Nutrient absorption capacity, photosynthetic area accumulation, water use efficiency (WUE) among others. Similar results were reported by Gray, (1990) that leaf characters like lamina length, width, petiole length, width and height changes as the environment changes. Similar observations on association of different traits with leaf yield was also reported by Sarkar et al., (1987), Tikader and Roy (2001), Tikader and Dandin (2005) and Vijayan et al. (1997).

Table 3: Pearson's correlation coefficient matrix for the different quantitative traits across the different environments.

	lamina length	lamina width	leaf area	bud length	petiole length	internode distance	number of branches	number of tillers	plant height	Number of diseased leaves	number of leaves destroyed by pests	100leaf weight	total plant biomass
lamina length													
lamina width	0.881***												
leaf area	0.95	0.95											

	1***	9***											
bud length	0.096***	0.091***	0.09**										
petiole length	0.4933***	0.414***	0.4584***	0.2198***									
internode distance	0.398	0.316***	0.3361***	0.1624***	0.2817***								
number of branches	-0.163***	-0.1781	-0.2006	0.2312***	-0.056	-0.031							
number of tillers	-0.0945	-0.0933	-0.1049	-0.2402	-0.0446	-0.0625	-0.0139						
plant height	0.4403***	0.37***	0.4032***	0.2751***	0.4526	0.2584***	0.0829	-0.1487					
Number of diseased leaves	0.0174	0.044	0.0336	0.6073***	0.1465***	0.0914***	0.2838***	-0.1565	0.3948***				
number of leaves destroyed by pests	0.0725	0.106***	0.0949***	0.5274***	0.1883***	0.1657***	0.2641***	-0.1233	0.4103***	0.0853			
100leaf weight	0.5805***	0.5671***	0.601***	-0.3435	0.3114***	0.1767***	-0.1861	0.0457***	0.3824***	-0.1097	-0.0117		
Leaf yield/plant	0.3374***	0.3197***	0.3252***	0.0577	0.3261***	0.2065***	0.2644***	0.0272***	0.6744***	0.3691***	0.4755***	0.4599***	

Conclusion

The results obtained in this study revealed that there was a slight difference in the agronomic performance of these mulberry varieties. According to the findings above, it can be concluded that Kanva2 which produced the highest number of branches and Thailand with highest leaf yield can be recommended for selection as good cultivars for farmer utilization in different geographical regions of Uganda since the main goal of mulberry production is high yield of leaves for silk worm production. This study has helped bridge the knowledge gap regarding different mulberry accessions and their performance in different parts of the country and this forms basis of proper and appropriate selection of the tropical cultivars based on the morphological traits for the farmers in Uganda. But it has been revealed that pests and diseases, genetic diversity directly affected leaf yield of mulberry therefore further research should be conducted to study pests and diseases of mulberry and their management, genetic diversity of different mulberry accessions and their contribution to adaptation to different agro-ecological environments. Future experiments should also consider evaluating these varieties over more locations to be able to determine the best adapted mulberry varieties with acceptable performance regardless of the season of cultivation.

Acknowledgement

We express our warm, deepest and heartfelt appreciation to our supervisor, Dr. Clet Wandui Masiga, Executive Director, Tropical Institute of Development Innovations (TRIDI), Uganda, for his unconditional guidance, invaluable advice, technical help and encouragement throughout this study. Thanks to the government of Uganda through the Ministry of Science and Technology for funding the commercialization of sericulture and apiculture technologies in Uganda.

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