ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Journal of Agronomy

ISSN 1812-5379
DOI: 10.3923/ja.2016.173.178

Research Article

Evaluation of Mulberry (*Morus* spp.) Genotypes for Growth, Leaf Yield and Quality Traits under Southwest Ethiopian Condition

Waktole Sori and Wosene Gebreselassie

College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia

Abstract

Background and Objective: Mulberry, *Morus* spp., a temperate plant well adapted to tropical and subtropical climatic conditions gives continuous yield, the leaf, which is used as a sole nutrient source for mulberry silkworm, *Bombyx mori* L. The plant is commonly grown in Ethiopia as a fence. The experiment was initiated to evaluate different mulberry genotypes for agronomic and quality attributes as a feed for silk worm. **Methodology:** Eleven locally available genotypes were collected and evaluated for their growth, leaf yield and attributes under Jimma conditions for 2 years using a randomized complete block design, each replicated thrice. **Results:** There were statistical differences in growth, leaf yield and quality attributes among the genotypes. Generally, Kumbi and M4 genotypes were superior in their growth, yield and quality attributes. Better establishment, maximum shoot length, number of leaves and branches, leaf area, internodes length, leaf fresh and dry weight, leaf yield per hectare and per plant, total chlorophyll, moisture percentage, total soluble protein, total soluble sugar and NPK contents of the leaf were obtained from Kumbi collection followed by M4 genotype in all cases. Minimum growth, leaf yield and leaf quality attributes were recovered from genotype S13 followed by Saja. **Conclusion:** Kumbi and M4 genotypes are recommended for mulberry garden establishment as future planting material sources and further multiplied for silkworm rearing purpose in Jimma area. However, the need for further studies was suggested to investigate the effects of the genotypes on the quantity and quality of mulberry silkworm silk cocoon production.

Key words: Mulberry genotype, silkworm, *Bombyx mori*, growth attribute, quality trait

Received: February 10, 2016 Accepted: June 30, 2016 Published: September 15, 2016

Citation: Waktole Sori and Wosene Gebreselassie, 2016. Evaluation of mulberry (*Morus* spp.) genotypes for growth, leaf yield and quality traits under Southwest Ethiopian condition. J. Agron., 15: 173-178.

Correspon ding Author: Waktole Sori, College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia Tel: +251 917 804341

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Ethiopia has diverse climatic conditions congenial for the cultivation of many crops of tropical, subtropical and temperate origin. One of the many crops of temperate origin suitable to Ethiopia's climatic condition is mulberry, *Morus* spp. Mulberry is a perennial crop cultivated for more than 15 years for its leaves as a sole feed source for mulberry silkworm, *Bombyx mori* L.[1]. Mulberry silkworm, *B. mori* is a monophagous fully domesticated useful insect in the order Lepidoptera and family Bombycidae, the larvae of which produces the silk. Silk being the most prized natural protein fiber known as "Queen of textiles" because of its quality and durability is produced by many silkworms, the most important being mulberry silkworm, *B. mori*. The *B. mori* depends solely on mulberry leaves for its nutrition. The nutritional quality of mulberry leaf greatly influences the growth and development of the larvae as well as cocoon and silk production of *B. mori*[2,3] besides environmental factors and adoption of technologies for better silkworm growth, development and cocoon production[4].

Sericulture is an important agro-based occupation of resource poor farmer of the world playing a major role in poverty alleviation by providing employment in the rural areas. Sericulture is characterized with high employment potential, low capital investment and it is highly remunerative. In traditionally sericultural countries like India, with improved production practices, 75 mt ha^{-1} $year^{-1}$ mulberry leaf[5] and well above 30 kg/100 dfls (diseases free laying) of cocoon[6] can be harvested. In many developing countries of the world sericulture has occupied an important place in socio-economic development of the farming communities. However, in Ethiopia, despite its long time introduction and congenial climatic condition for the cultivation of host plants and rearing of silkworm species, sericulture has not yet been fully practiced by the farming communities. Presently, the government of Ethiopia through the Federal Ministry of Agriculture and Regional Bureaus of Agriculture has established Apiculture and Sericulture implementation strategy and there is case team at each woreda (Ethiopian administrative structure equivalent to district) throughout the country. However, adoption is not what was expected primarily due to lack of market for cocoons, land shortage, limited skill and knowledge and lack of seed[7].

Nevertheless, the continuous rise of unemployed educated youth, presence of sufficient land in the rural areas for cultivation of host plants and availability of irrigation water, conduciveness of the climatic condition for cultivation of mulberry and rearing of silkworms, availability of microfinance/loan, availability of the skills and knowledge of sericulture at educational institutions and agricultural research centers and multiple production of cocoons per year makes sericulture an ideal agro-based practice for Ethiopian agriculture. Traditionally, mulberry sericulture has two important components, the mulberry and the silkworm. Availability of mulberry leaf is the key factor that decides the success and sustainability of sericulture. Quality and quantity of mulberry leaf production depends on mulberry variety/genotype[8], cultivation practices, soil moisture and nutrient status, pests and diseases management both on mulberry plant and the silkworm[9]. Quality cocoons are produced when developing silkworm larvae are fed with quality mulberry leaves[10]. Sixty percent of the cost of silk cocoon production is spent for mulberry cultivation[11,12]. Hence, cultivation of mulberry plants deserve due attention in mulberry sericulture industry. Leaf quantity and quality are important parameter used for evaluation of mulberry varieties aimed at selection of superior varieties for enhanced rearing performance[8]. Superior mulberry variety is important to sustain the sericulture industry. Therefore, there is a need to establish mulberry gardens for continuous supply of mulberry cuttings and the seeds for host plant cultivation to farmers. In this study, therefore, different mulberry genotypes available throughout the country were collected and evaluated for their agronomic characteristics and quality attributes for two years under Jimma conditions.

MATERIALS AND METHODS

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) agricultural experimental station, Eladalle, Jimma-Ethiopia in 2014 and 2015 cropping seasons. The study materials were 11 mulberry genotypes, mainly grown as a fence and/or shade around home garden; collected from central, South and Southwestern parts of Ethiopia and brought to JUCAVM. Mulberry cuttings with three eye buds were prepared from each genotype and planted at a spacing of 60 cm between plants and 90 cm between rows on 5.4$\times$3.5 m plot size. Similar agronomic practices were applied to each plot. The plants were maintained for 1 year and pruned at ground level at the beginning of the 2nd year immediately at the onset of the main rainy season (early June, 2014 and again pruned early June, 2015). The experiment was laid out in a Randomized Complete Block Design (RCBD) with 11 genotypes and three replications. Data on growth, yield and quality variables such as stand count, shoot length, leaf and shoot per branch number, leaf area, internodes length, fresh and dry leaf weight, fresh leaf yield per hectare and plant, total chlorophyll, percentage leaf moisture, total soluble sugar and protein and NPK content of the leaf were collected 45 and 90 days after bottom pruning (DAP).

Leaf moisture was determined by the oven drying method using the formula developed by AOAC[13] as follows:

$$\text{Moisture content (\%)} = \frac{\text{Fresh leaf weight} - \text{Oven dry leaf weight}}{\text{Fresh leaf weight}} \times 100$$

Leaf area was determined using leaf area meter. Total soluble protein, total soluble sugar and total chlorophyll content of the leaf were determined by the methods of Lowry *et al.*[14], DuBois *et al.*[15] and Hiscox and Israelstam[16], respectively. Nitrogen, phosphorus and potassium contents in leaf were analyzed as per the standard procedures[17]. Finally, analysis of variance was performed using SAS software[18] package version 9.2 and treatments found significant were compared using Least Significance Difference (LSD) method at 5% level of significance.

RESULTS AND DISCUSSION

The analysis of variance on mulberry growth, yield and quality variables for the 2 years data showed significant difference ($p<0.05$) among genotypes and the results of each variable is presented and discussed.

Mulberry growth variables: Mulberry cutting establishment (stand count), average shoot length, average number of leaves per plant (Table 1), average number of shoots per plant, average leaf area (Table 2) and average internodes length (Table 3) were found to be statistically significantly different ($p<0.05$) among the genotypes compared.

In terms of mulberry cuttings establishment (stand count) from the 16 cuttings planted in a plot, on an average 15.67 cuttings were established for kumbi, M4, K2 and Gatama genotypes which were statistically similar with Awassa, Anno, Bedele and Saja genotypes. On the contrary, S-13 was poorly established with 10 cuttings failing to establish among the 16 cuttings planted indicating its poor adaptation to Jimma condition. Maximum and significantly ($p<0.05$) higher shoot length of 43.27, 92.80 and 109.67 cm was recorded from kumbi genotype on 45, 90 and 135 days of bottom pruning, respectively assuring its better growth performance under Jimma condition (Table 1). Similarly, maximum leaf (57.33, 96.17 and 98.00) and shoot number (3.93, 5.33 and 5.07) per plant on 45, 90 and 135 DAP respectively, leaf area (132.33 cm^2) and internodes length (4.40 and 4.13) on 45 and 90 DAP were obtained from kumbi genotype followed by M4 (Table 1-3). The least and significantly lower growth attributes of mulberry was recorded from S-13 genotype in all cases. This might be because of the genetic nature of the genotypes and relatively less conduciveness of Jimma condition for S-13 and better congeniality of the condition for Kumbi and M4 mulberry genotypes. Differences in mulberry genotypes in growth, yield and quality attributes are expected because of the heterozygous and cross pollinating nature of mulberry. Madan and Sharma[19] reported differential responses of three mulberry varieties (Sujanpuri, Kanva-2 and a local) in terms of above ground biomass and leaf yield both under irrigated and rainfed conditions. Chowdhury *et al.*[20] reported that the use of organic inputs such as vermi-wash, bio-fertilizers, enriched vermi-compost, green manuring were highly effective, sustainable and economical in improving the growth characters and quality attributes of S-1635 variety of mulberry under irrigated conditions in gigantic alluvial soil condition of West Bengal in India.

Table 1: Mulberry stand count, shoot length and leaf number as affected by genotypes under Jimma condition

		Average shoot length (cm)			Average number of leaves per plant		
Genotypes	Stand count	45 DAP	90 DAP	135 DAP	45 DAP	90 DAP	135 DAP
Saja	15.00^{abc}	22.00^{i}	51.51^{g}	62.00^{e}	27.33^{fg}	48.07^{f}	55.33^{g}
Kumbi	15.67^{a}	43.27^{a}	92.80^{a}	109.67^{a}	57.33^{a}	96.17^{a}	98.00^{a}
M4	15.67^{a}	38.54^{b}	80.03^{b}	107.00^{a}	43.67^{b}	89.43^{b}	89.00^{b}
Melkassa	14.33^{bc}	24.56^{h}	51.18^{g}	62.67^{e}	24.33^{gh}	49.63^{f}	61.33^{f}
S13	6.00^{d}	18.37^{j}	38.90^{h}	48.00^{f}	22.00^{h}	41.67^{g}	47.33^{h}
K2	15.67^{a}	29.34^{f}	63.70^{e}	80.67^{d}	31.33^{e}	69.17^{c}	77.33^{cd}
Awassa	15.33^{ab}	25.23^{h}	56.56^{f}	67.33^{e}	26.67^{fg}	56.33^{e}	68.33^{e}
Hijaji	14.00^{c}	32.01^{e}	71.38^{d}	88.00^{c}	36.00^{d}	71.60^{c}	80.00^{c}
Ano	15.33^{ab}	27.34^{g}	60.47^{ef}	74.33^{d}	29.33^{ef}	63.03^{d}	74.00^{d}
Gatama	15.67^{a}	35.78^{c}	77.13^{bc}	107.33^{a}	40.00^{c}	88.60^{b}	94.67^{a}
Bedele	15.33^{ab}	34.33^{d}	75.00^{cd}	95.67^{b}	36.00^{c}	84.93^{b}	90.00^{b}
CV (%)	4.66	2.57	3.64	4.60	5.68	3.64	3.56
LSD (5%)	1.14	1.32	4.05	6.43	3.29	6.03	4.61
F-test	*	*	*	*	*	*	*

*Significant at 5% level significance, means within column followed by the same alphabetical letter(s) are non-significantly different from each other ($\alpha = 5\%$), DAP: Days after bottom pruning

Table 2: Number of shoots and leaf area of mulberry plant as affected by genotypes under Jimma condition

	Average No. of shoots per plant			
Genotypes	45 DAP	90 DAP	135 DAP	Average leaf area (cm^2)
Saja	3.30^{bc}	3.83^{c}	3.47^{d}	72.00^{ef}
Kumbi	3.93^{a}	5.33^{a}	5.07^{a}	132.33^{a}
M4	3.87^{a}	5.03^{ab}	4.40^{b}	106.00^{b}
Melkassa	3.87^{a}	3.93^{c}	3.53^{d}	77.00^{ed}
S13	2.20^{d}	3.83^{c}	3.00^{e}	71.00^{ef}
K2	2.60^{d}	4.47^{bc}	4.00^{bc}	81.33^{cd}
Awassa	2.60^{d}	4.03^{c}	3.63^{cd}	70.33^{ef}
Hijaji	3.60^{ab}	4.40^{bc}	4.00^{bc}	74.67^{def}
Ano	3.13^{c}	4.03^{c}	3.57^{d}	69.00^{f}
Gatama	3.60^{ab}	4.47^{bc}	4.40^{b}	100.67^{b}
Bedele	3.50^{abc}	4.43^{bc}	4.30^{b}	88.33^{c}
CV (%)	8.28	10.14	6.27	5.25
LSD (5%)	0.46	0.75	0.42	7.66
F-test	*	*	*	*

*Significant at 5% level of significance, means within column followed by the same alphabetical letter(s) are non-significantly different from each other (α = 5%), DAP: Days after bottom pruning

Table 3: Internodes length of mulberry plant as affected by genotypes under Jimma condition

	Average internodes length (cm)	
Genotypes	45 DAP	90 DAP
Saja	3.63^{d}	3.73^{cd}
Kumbi	4.40^{a}	4.13^{ab}
M4	4.13^{b}	4.00^{bcd}
Melkassa	3.50^{d}	3.70^{d}
S13	3.90^{c}	3.97^{bcd}
K2	4.40^{a}	4.40^{a}
Awassa	3.83^{c}	3.83^{bcd}
Hijaji	3.83^{c}	4.03^{bc}
Ano	4.13^{b}	3.83^{bcd}
Gatama	4.13^{b}	3.93^{bcd}
Bedele	3.97^{c}	4.00^{bcd}
CV (%)	2.17	4.52
LSD (5%)	0.15	0.03
F-test	*	*

*Significant at 5% level of significance, means within column followed by the same alphabetical letter(s) are non-significantly different from each other (α = 5%), DAP: Days after bottom pruning

Mulberry leaf yield: Maximum and significantly ($p<0.05$) higher quantity of fresh (27.00 g) and dry (7.73 g) leaf weight for five randomly plucked mulberry leaves was recorded from Kumbi genotype followed by M4, 25.00 g and 7.20 g/5 leaves for fresh and dry weight respectively (Table 4). This is because these genotypes had maximum leaf area that contributed for overall increased fresh and dry leaf weight showing their better adaptation to Jimma environmental conditions. On the other hand, S-13 followed by Saja genotype had the lowest fresh (13.67 g/5 leaves) and dry (3.67 g/5 leaves) leaf weight, indicating poor adaptability of the genotype to the area. Also, quantitative fresh leaf yield per hectare, 19.60 t and per plant,

Table 4: Mulberry leaf biomass and fresh leaf yield as affected by genotypes under Jimma condition

	Average fresh leaf weight of five leaves (g)	Average dry leaf weight of five leaves (g)	Fresh leaf yield	
Genotypes	45 DAP	45 DAP	Per hectares (t)	Per plant (g)
Saja	16.00^{e}	4.33^{g}	15.30^{i}	141.33^{h}
Kumbi	27.00^{a}	7.73^{a}	19.60^{a}	358.33^{a}
M4	25.00^{b}	7.20^{ab}	18.73^{b}	353.33^{a}
Melkassa	16.33^{e}	5.13^{f}	15.70^{h}	157.00^{g}
S13	13.67^{f}	3.67^{h}	14.70^{j}	130.67^{h}
K2	18.33^{d}	5.90^{ed}	16.27^{ef}	238.00^{d}
Awassa	16.33^{e}	5.30^{ef}	15.77^{gh}	177.67^{f}
Hijaji	19.00^{cd}	5.83^{de}	16.60^{e}	269.33^{c}
Ano	19.00^{cd}	6.10^{d}	16.13^{fg}	196.33^{e}
Gatama	24.33^{b}	7.00^{cb}	17.93^{c}	291.00^{b}
Bedele	20.33^{c}	6.47^{cd}	17.50^{d}	277.67^{bc}
CV (%)	5.92	6.47	13.28	3.66
LSD (5%)	1.97	0.65	0.38	14.68
F-test	*	*	*	*

*Significant at 5% level of significance, means within column followed by the same alphabetical letter(s) are non-significantly different from each other (α = 5%), DAP: Days after bottom pruning

358.33 g were obtained from Kumbi collected genotype. This is because this genotype had maximum shoot length, leaf and shoot number, leaf area, fresh and dry leaf weight than other genotypes that positively influenced the fresh leaf yield obtained both on hectare and plant basis.

Mulberry leaf quality variables: Leaf quality variable such as total chlorophyll, moisture percentage, soluble protein and sugar and NPK content of the leaves of different genotypes tested were statistically significantly ($p<0.05$) different among the genotypes (Table 5). However, Kumbi genotype recorded maximum total chlorophyll (1.77 mg g^{-1}), moisture percentage (78.73%), soluble protein (8.31 mg g^{-1}), soluble sugar (48.89 mg g^{-1}), percentage N (4.29%), P (0.45%) and K (1.92%) content of the leaf. Kumbi genotype was followed by M4 and Gatama in all quality variables. On the other hand, S-13 followed by Saja genotype registered minimum quality variables (Table 5). More moisture content of the leaf is positively correlated with palatability and assimilability of nutrients by the feeding larvae of silkworm[21]. Leaf water content positively influences the growth and development of mulberry silkworms by increasing leaf ingestion and digestion capacity of the silkworms because it has gustatory and olfactory stimulant effects[22]. They further stated the direct relationship between mulberry leaf quality and larval food consumption, larval growth, digestive coefficient and food absorption by silkworm larvae. Leaf moisture content and moisture retention rate are important qualitative variables of mulberry leaf especially from the point of young age silkworm

Table 5: Mulberry leaf quality variables as affected by genotypes under Jimma conditions

Genotypes	Total chlorophyll (mg g^{-1})	Moisture (%)	Soluble protein (mg g^{-1})	NPK content of the leaf (%)			Soluble sugar (mg g^{-1}) of fresh weight
				N	P	K	
Saja	1.62^{c}	65.33^{g}	5.29^{ef}	3.35^{d}	0.28^{ef}	1.66^{e}	33.89^{i}
Kumbi	1.77^{a}	78.73^{a}	8.31^{a}	4.29^{a}	0.45^{a}	1.92^{a}	48.89^{a}
M4	1.66^{b}	76.00^{b}	7.41^{b}	3.85^{b}	0.43^{a}	1.86^{b}	46.89^{b}
Melkassa	1.63^{cb}	65.23^{g}	5.49^{de}	3.31^{d}	0.28^{ef}	1.70^{d}	35.00^{h}
S13	1.61^{c}	65.43^{g}	5.03^{f}	3.35^{d}	0.26^{f}	1.58^{f}	31.44^{j}
K2	1.61^{c}	69.20^{e}	6.41^{c}	3.60^{bcd}	0.31^{d}	1.73^{cd}	40.89^{f}
Awassa	1.65^{b}	67.20^{f}	5.44^{de}	3.36^{d}	0.28^{ef}	1.72^{cd}	35.89^{h}
Hijaji	1.64^{cb}	71.60^{d}	6.52^{c}	3.49^{cd}	0.35^{c}	1.71^{d}	43.68^{e}
Ano	1.65^{cb}	68.47^{e}	5.74^{d}	3.41^{d}	0.30^{de}	1.72^{cd}	36.89^{g}
Gatama	1.64^{cb}	74.73^{c}	7.39^{b}	3.75^{bc}	0.40^{b}	1.75^{c}	45.89^{c}
Bedele	1.64^{cb}	74.73^{c}	7.20^{b}	3.55^{bcd}	0.37^{c}	1.73^{cd}	44.79^{d}
CV (%)	11.16	9.75	3.04	5.23	3.89	11.58	13.70
LSD (5%)	0.03	1.17	0.33	0.32	0.02	0.03	0.94
F-test	*	*	*	*	*	*	*

*Significant at 5% level of significance, means within column followed by the same alphabetical letter(s) are non-significantly different from each other (α = 5%)

rearing[23]. They reported V_1 and M_5 mulberry varieties with highest and lowest moisture retention capacity, respectively among five varieties they studied in southern India. In a separate study on mulberry quality attributes, Horie[24] reported that total nitrogen, total soluble sugar and total soluble protein are the most important biochemical constituents of mulberry leaf that positively favors silkworm larval growth and cocoon yield. This is because it is the leaf nitrogen which is converted to the silkworm protein, the silk.

The highest total chlorophyll content of genotype Kumbi might be associated with better photosynthetic efficiency of the genotype that leads to better yield of the leaf and its quality. Higher level of leaf chlorophyll is indicative of photosynthetic efficiency of the plant system[9]. Urea, sulphate of ammonia and NPK application to different mulberry variety had significant impact on growth and quality variables of the varieties[25]. On the contrary, application of NPK, piggery dung and *Leucaena leucocephala* leaves had no significant effect on mulberry leaf quality but on fat content, growth and yield potential of mulberry plant[26]. According to the study conducted in India by Reddy *et al.*[27], multi-nutrient foliar application had a positive influence on growth, yield and quality attributes of V1 mulberry variety. Caccam and Mendoza[28] opined the use of sustainable and organic farming techniques can be a good alternative to conventional farming to improve the productivity of sericulture farms. Whereas combined application of organic and inorganic fertilizers were recommended for better mulberry growth and leaf quality[29]. Organic farming approaches contributes for an increased growth and quality attributes[20,30] of mulberry and its sustainable quality leaf production and further reduces the incidence of pests on mulberry and increases the feed utilization and growth of silkworm, *B. mori*[30]. Application of nutrient phosphorus[31] and potassium[32] significantly influences the growth attributes, yield, nutrient uptake and economics of mulberry significantly.

CONCLUSION

Among the genotypes compared in this experiment Kumbi and M4 genotypes were found to adapt and perform better than the remaining nine genotypes under Jimma environmental conditions. Therefore, considering the growth attributes, leaf yield and quality variables studied, these two genotypes could be recommended for the area for immediate use though undoubtedly more genotypes from different mulberry growing areas should be brought and tested for leaf yield and quality attributes. In addition, the existing materials need to be further tested over a wide range of location and years to determine their differential response at different environments and develop stable genotypes that could be recommended to a wider range of environments focusing on resource poor farmers who may not afford commercial agricultural inputs.

ACKNOWLEDGEMENT

We are grateful to Jimma University College of Agriculture and Veterinary Medicine for providing financial support for the research.

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