

# Effect of Spacing on Performance of *Morus* Species

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**Abstract**— The effect of spacing on performance of *Morus* species, was studied. The study was aimed to determine the correlation between spacing and the growth parameters of five introduced *Morus* species namely (*Morus alba*, *M. mallofolia*, *M. tiliaefolia*, *M. acidosa* and *M. mesozygia*). The study was conducted in Forest National Corporation (FNC) in Dindir town, Sinnar State, during the period 2000-2002. Sequential experiments were conducted on five mulberry species and planting space. Uniform propagules of the five mulberry species were planted in the field, to assess their survival and leaves yield, for five spacing (0.6 x 0.75m, 0.50 x 1.00m, 1.00 x 1.00 m, 1.00x1.50m and 2.00 x 2.00m). A randomized complete block design of five replicates were used. The spacing were randomly designed to plots in each replication and the propagules of five species were randomly assigned with each plot. The effect of species and spacing were determined by assessed the growth parameters of each species planted in each spacing in specific period of growth (age). The result revealed that spacing and species have significant effect on growth parameters, where the planting space and species had marked effect on tree growth. High leaves number was obtained from the species *Morus alba*, followed by *Morus mallofolia* and *M. acidosa*. Also *M. alba* and *M. mesozygia* gave high weight of leaves. In conclusion this study showed the spacing 1.00 x 1.00 m and 1.50x 1.00 m gave higher yield per unit area, than the other spacing treatments. While *M. alba* and *M. mesozygia* showed high yield than the other tested species. The recommended spacing is 1.00 x 1.00m and 1.50 x 1.00 m. Further studies are needed to study the effects of this fact on the quantity and quality of the silk produced by the silk worms feed on leaves. This study claim to be first report on silvicultural performance concerning effect of species and spacing of mulberry in Sudan, which may help and contribute on farmer's revenues perhaps national income and defeat abject poverty in rural areas.

**Index Terms**— Mulberry, Effect of spacing, Species, Growth

## I. INTRODUCTION

Mulberry (*Morus* L) is an economical important tree, being cultivated for its leaves, to rear silkworm *Bombyx mori* [1]. Mulberry has long been cultivated, for silkworm rearing. Mulberry is a perennial and broadleaf plant [2]. Taxonomically, mulberry belongs to the genus *Morus* L and has more than 68 species [3]. Mulberry (*Morus alba*) is a shrub tree, it belong to family Moraceae and to the genus *Morus*, with more than 30 species and 300 varieties. It comes

from China and other species originate in other temperate countries, 25 ton of dry mass can be produced from a single ha per year, with 25000 plants [4]. In recent year, the role of

mulberry tree in the prevention and control of desertification, water and soil conservation, saline land management and forage for livestock [2]. Rearing of silkworm is an art and science; popularly known as sericulture and agro based cottage industries provide employment, to million in China, India, Korea and Vietnam. Mulberry is a perennial tree that maintains high heterozygosity due to out breeding reproductive system [1]. Mulberry Leaves powder can substitute up to 30% of commercial feed on and reduce cost of 24.8 % [5]. The genus *Morus* L. is highly heterozygous, with a lot of variation, in the off springs. Propagation of mulberry is done, through vegetative means, such as planting of cuttings or by grafting so as to reserve, the phonological characters [6]. Survival rate is considered, as one of the important criteria as mulberry varieties are propagated though vegetation means [7]. Triploid mulberry varieties usually reveal more than 96% survivability rate [8].

Nine mulberries were planted at the National Agricultural Research Centre Islamabad in 1983, in trial for silk worm rearing. Eight were exotic (*M. catfolia*, *ichihine*, *husung*, *shinichinose Morus indica*, gumjijapafleSe late and Japanese e & l) and one local (*Morus alba*). Inter plant and inter row distances were 1m and plants were flood irrigated 11 times per month [9]. In Brazil used spacing of 1.5x 1.0m [10]. A study between 1989 and 1991 determined the spacing of single or double rows of mulberry, in dense mechanized plantation in Korea republic that, the leaf yield in single row plots, with spacing 1.2 x 0.4m, increased by 20-44% relative to control (double row) plots which had spacing 1.8 + 0.6m x 0.5m) The results indicated that the single plantation was more suitable than control plots for mechanization [11]. Distance between lines and that between plants 60-45cm, leaf yield/significant affects of variety was found for plant height among the treatment [12]. Mulberry species can be propagated by from stem cuttings under forest nursery condition with high survival rate. Cutting from Defoliated plants (8-10 days before cutting the branches) gave 100% rooting for the (*Morus alba*, *M. mallofolia*, *M. acidosa*, *M. mesozygia* and *M. tiliaefolia*) [13]. A suitable pruning height for these five *Morus* species is 40cm above ground level to produce high foliage every 3-4 months [14]. In 1994 Sudan represented FNC was introduce five *Morus* species namely (*Morus alba*, *M. mallofolia*, *M. acidosa*, *M. mesozygia* and *M. tiliaefolia*) as these species were introduced in the first time except *M. mesozygia* which was introduced by Horticulture Department before FNC, and the knowledge of the silvicultural performance of these species in Sudan is scanty. For this reason the aim of this

study was to determine the effect of spacing on performance of *Morus* species.

## II. MATERIALS AND METHODS

### Study area:

The study was conducted in forest Nursery in Dindir town, Dindir locality, Sinnar State, during the period 2000 — 2002. Planting site was located near Dindir town, along the Dindir River on groves site. It situated in locality of Sinnar State, at latitude  $13^{\circ} 45' - 11^{\circ} 45' N$  and longitude  $35^{\circ} 30' - 33^{\circ} 45' E$ . The soil is alkaline clay (pH of 8.3) and mostly alluvial along the Dindir river banks and heavy cracking clay away from the river.

The area is poor savanna wood land in the north and rich savannah wood land in the south. The weather is generally hot and dry with short rainy season between June and September. The mean annual rainfall is between 400 and 450 mm in the North and between 600 mm and 1000 mm in South (Dindir National Park). Temperature ranges between 20 C and 42 C.

### Field Test

The rooted cuttings were planted in a site near the nursery to study the effect of species, planting space, on plant growth. The site area was 0.11 ha located thirty meters away from Dindir river (Cliff land). The area was cleaned from bushes, grasses and trees and then the land was ploughed, harrowed and leveled manually, using the hand tool commonly called “Wasug”. The area was then divided into plots with dimensions of 15 x 7m. The whole area was fenced. Water was pumped through a main canal and passed to the plots through a system of canalization between the plots. Irrigation was applied immediately after planting and every 3- days afterwards.

### Planting of Plants

Uniform propagules were transferred from the nursery and planted in the designated plots according to the tested spacing in April 2000 within two days period.

Weeding was done weekly in the first two months. The canals and water catchments were reshaped to catch water for plant in plots (5).

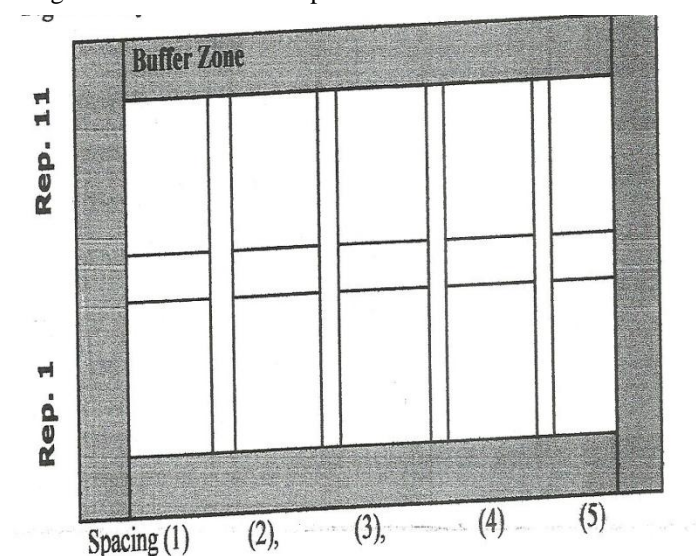
### Treatments

The five species that were propagated by stem cuttings were tested in the field for survival and vegetative growth. The species were: *Morus alba*, *Morus acidosa*, *Morus maiotifolia*, *Morus mesozygia*, and *Morus tiliaefolia*. Five different spacings/treatment between plants were tested: Spacing 1 (0.6 x 0.75m), spacing 2 (0.5 x 1m), spacing 3 (1 x 1m), spacing 4 (1.5 x 1m) and spacing 5 (2 x 2m) each spacing was represented by a plot within each replication as described in figure 1. Spacing 5 was heavily affected by rats and was not included in the statistical analysis.

planting space, on tree growth parameters. The parameters for each tree were height, number of leaves, and number of branches, weight of leaves, and weight of branches.

### Layout and design

The planted area (0.11 ha) was divided into two replications. Each replication was divided into 5 plots of 7 x 1 5m each. Each plot was used for the spacing levels as shown in figure (1). One line tree was planted between rows and around the replications as buffer zone. The five species were randomly assigned as rows within the plots.



**Figure 1:** layout of the field experiment

Spacing (1) (0.6 x 0.75m) consists of 16 rows with 144 plants (9 x 16), Spacing (2) (0.5 x 1m) consists of 18 rows with 72 plants (18 x 4), Spacing (3) (1 x 1 m) consists of 12 rows with 48 plants (12 x 4),

Spacing (4) (1.5 x 1 m) consists of 10 rows with 40 plants (10 x 4),

Spacing (5) (2 x 2m) consists of 9 rows with 18 plants (9 x 2), Buffer zone: Each plot had surrounding external boundaries (Buffer Zone) consist of one row of plants, which received the same treatment as the plot, but not considered in the assessment (measurements).

The five species tested were randomly planted with rows.

### Assessment

The assessment was carried for the original plants and the coppice thereafter.

The plants were assessed for survival, plant height, number of leaves and number of branches after one month, 2 months, 3 months and 4 months from planting.

### Statistical analysis

The statistical analysis system (SAS) was used for data analysis Duncan's multiple range test was used to determine significance of difference between means. General linear model procedure was used to determine significant effect of

### III. RESULTS

#### Spacing effect

##### Original growth

The spacing effect increased with time. In the first measurement (one month after planting) the effect of spacing was not significant in height, leaves number and branches number (Table 1a). However, in the subsequent measurement the effect of spacing was significant (Table 1b and c). The spacing (1 x 1 m) and (1.5 x 1 m) spacing 3 and 4 gave significantly high values compared to the smaller spacing. Spacing 5 (2 x 2 m) gave higher values in the second measurement but as mostly affected by rats.

##### Effect species and spacing on survival

The survival was significantly affected by species within the five spacing at the four measurements. *M. mallotifolia*, *M. acidosa* and *M. mesozyga* showed higher survival percent compared to *M. alba* and *M. tiliaefolia* (Table 2 a, b, c and d). The survival was high at the wide spacing (spacing 2 and 4) compared to spacing 1 and 2 (Table 2).

Spacing 1: In measurement 1, *M. acidosa* and *M. mesozyga* showed high survival percent (100%) while *M. tiliaefolia* had the lowest survival percent (55%) in measurement 1. The survival decreased in measurement 2 with similar trend as in measurement 1. The survival dropped for *M. acidosa* to 87% and *M. tiliaefolia* to 50% in measurement 4 (Table 2 a, b, c and d).

Spacing 2: In measurement 1, the survival was higher than spacing 1 with 100% for four species and 75% for *M. tiliaefolia*. In the subsequent measurements the survival dropped similar to spacing 1 (Table 2).

Spacing 3 and 4: The survival percent was high for all the species and measurements ranging from 87 to 100%.

Spacing 5: The survival was less than spacing 4 due to the damage caused by rats.

**Table (1)**

Average pooled height (cm), number of branches, number of leaves and survival for the five *Morus* species original growth at five spacing.

**(A): First measurement (1. month in the field)**

Spacing (m)	Height (cm)	Number of branches	Number of leaves	Survival %
0.6 x 0.75 m	48.58a	5.48a	44.92 a	88.30 a
0.5 x 1m	45.76 a	4.60a	38.17 a	94.60 a
1 x 1 m	43.30 a	5.38a	44.59 a	96.10 a
1.5 x 1 m	48.38 a	6.62a	53.78 a	96.70 a
2 x 2 m	34.38 a	5.90a	30.32 a	87.50 a
Pr =	0.0012	0.18	0.0006	0.32

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(B): Second measurement (2 month in the field)**

Spacing (m)	Height (cm)	Number of branches	Number of leaves	Survival %
0.6 x 0.75 m	81.67 a	9.65 cb	107.42 b	86.62 a
0.5 x 1m	78.50 a	9.54cb	98.59b	92.75 a
1 x 1 m	86.21 a	15.43 ab	166.73 a	97.37 a
1.5 x 1 m	95.20 a	19.06 a	200.82 a	98.33 a
2 x 2 m	42.84b	6.92 c	38.62c	87.50 a
Pr =	0.0012	0.18	0.0006	0.32

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

## (C): Third measurement (3 month old plants)

Spacing (m)	Height (cm)	Number of branches	Number of leaves	Survival %
0.6 x 0.75 m	104.29 a	9.83 b	117.95 b	73.84 b
0.5 x 1m	102.94 a	10.71 b	129.44 b	85.34 a
1 x 1 m	116.79 a	18.67 ab	197.66 b	96.05 a
1.5 x 1 m	114.30 a	22.00 a	211.15 ab	91.67 a
2 x 2 m	106.6 a	21.4 a	329.72 a	91.18 a
<b>Pr =</b>	<b>0.0012</b>	<b>0.18</b>	<b>0.0006</b>	<b>0.32</b>

Means with same letter in the same columns are not significantly at 0.05 level using Duncan multiple tests.

**Table (2)**

Survival percentages of five *Morus* species at five tested spacing(m).

## (A): Second measurement (1 month plants)

Species	Spacing (m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. acidosa</i>	100a	100a	100a	91.66a	62.5 a
<i>M.mesoZyga</i>	100a	100a	100a	100a	100a
<i>M.mallotfolia</i>	96.29 a	100a	91.67 ab	100a	100 a
<i>M. alba</i>	95.56 a	100a	100 a	100a	100a
<i>M. tiliaefolia</i>	55.56b	75b	83.33b	87.5	83.33 a
<b>Pr =</b>	<b>0.0001</b>	<b>0.0005</b>	<b>0.0009</b>	<b>0.33</b>	<b>0.16</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

## (B):

Species	Spacing (m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. acidosa</i>	93.33a	95.83 a	93.73 a	100a	62.5 a
<i>M.mesozyga</i>	92.85 a	85.00 cb	100 a	100a	100a
<i>M.mallotfolia</i>	91.11 a	100 a	100a	100a	100 a
<i>M. alba</i>	88.88.a	100a	100a	100a	100a
<i>M. tiliaefolia</i>	59.26b	81.25 c	91.66 a	91.66 a	83.33 a
<b>Pr =</b>	<b>0.002</b>	<b>0.006</b>	<b>0.0053</b>	<b>0.16</b>	<b>0.16</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

## (C):

Species	Spacing (m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. acidosa</i>	85.52 a	100 a	100 a	91.67 a b	100a
<i>M.mesoZyga</i>	80.56 a	83.33 a b	93.75 a	100a	75 a
<i>M.mallotfolia</i>	78.57 a	75 b	100a	100a	100 a
<i>M. alba</i>	75.56 a	87.5 ab	95 a	95 a	100a
<i>M. tiliaefolia</i>	52.78b	68.81 a b	91.66 a	91.66 a	83.33 a
<b>Pr =</b>	<b>0.03</b>	<b>0.33</b>	<b>0.72</b>	<b>0.1</b>	<b>0.34</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

## (D):

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 0.5x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. acidosa</i>	91.11a	94.44 a	100 a	91.67 a	100 a
<i>M.mesoZyga</i>	87.03 a	90 a	93.75 a	83.3 a	50 b
<i>M.mallotfolia</i>	82.14a	80 a b	100 a	100 a	100 a
<i>M. alba</i>	73.33	90.9 a	95 a	91.67 a	83.33 a b
<i>M. tiliaefolia</i>	50 b	69.44 b	100 a	87.5 a	100 a
<b>Pr =</b>	<b>0.0005</b>	<b>0.03</b>	<b>0.56</b>	<b>0.5</b>	<b>0.02</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

### Species effect

### Original growth

The pooled species effect was highly significant in the four measurements for height growth, number of branches and number of leaves (Table 3). *M. alba* have higher values

compared to *M. tiliaefolia* at age 1, 2, 3 and 4 month of growth in the field (Table 3 a, b, c and d).

Leaves and branch weight: The five species showed marked and significant different between them after five month from planting:

**Table (3)**  
Height(cm) ,number of leaves, number of branches and survival.  
(A):

Species	Height (cm)	Number of branches	Number of leaves	Survival %
<i>M. alba</i>	53.05 a	7.54 a	68.21 a	98.10 a
<i>M.mallotfolia</i>	47.65 b	4.94 b c	32.77 bc	95.20 a
<i>M. acidosa</i>	43.09 cb	5.87 b	45.19 b	97.50 a
<i>M.mesozyga</i>	40.83 c	4.34 c d	37.30 b	100.00 a
<i>M. tiliaefolia</i>	40.39 c	3.20 d	25.52 c	59.5 b
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

### (B):

Species	Height (cm)	Number of branches	Number of leaves	Survival %
<i>M. alba</i>	100.98 a	15.97 a	177.69 a	96.40 a
<i>M.mallotfolia</i>	82.97 b	14.12 b	138.14 b	92.40 a
<i>M. acidosa</i>	81.75 b	13.47 b	132.32 b	96.80 a
<i>M.mesozyga</i>	75.41 c	6.96 c	80.60 c	94.00
<i>M. tiliaefolia</i>	49.90 d	3.51 d	34.75 d	76.50 b
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.



## (C):

Spacing (m)	Height (cm)	Number of branches	Number of leaves	Survival %
<i>M. alba</i>	135.00 a	21.22 a	253.74 a	83.48 a
<i>M.mallofolia</i>	118.12 b	16.63b	189.75 b	92.77 a
<i>M. acidosa</i>	114.601,	17.41 b	186.73 b	85.74 a
<i>M.mesozyga</i>	99.42c	8.62 C	105.01 C	87.81 a
<i>M. tiliaefolia</i>	61.15d	4.21 d	45.90d	72.34b
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>

Means with the same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

## (D):

Spacing (m)	Height (cm)	Number of branches	Number of leaves	Survival %
<i>M. alba</i>	170.16 a	23.77 a	320.89 a	85.04 a
<i>M.mallofolia</i>	145.91 b	17.82b	250.48 b	86.11 a
<i>M. acidosa</i>	143.75 b	16.21b	224.92 b	93.81 a
<i>M.mesozyga</i>	130.32c	10.85 c	150.21 C	89.54 a
<i>M. tiliaefolia</i>	73.21 d	4.04d	51.49d	69.38b
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>

Means with the same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**Height growth within spacing**

The species varied significantly, on the original height growth, within each spacing at each of the four measurements. *M. alba* showed the highest height compared

to the other species. It has significantly higher height than *M. tiliaefolia*. Spacing 3 and 4 showed higher growth compared to the others (Table 4 a, b, c and d).

**Table (4)**

Mean plant height (cm) of the five *Morus* species at five spacing (m).

## (A):

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	56.46 a	46.66 b	54.55 a	53.66 a b	47.83 a
<i>M.mallofolia</i>	48.57 a b	42.65 b	40.90 c b	39.91 c b	34.13 a b
<i>M. acidosa</i>	48.36 a b	58.25 a	51.18 a b	36.33 c	33.00 a b
<i>M.mesozyga</i>	40.30 b	46.73 b	30.50 c	51.16 a b c	28.60 b
<i>M. tiliaefolia</i>	39.84 b	38.00 b	31.00 c	58.75 a	24.50 b
<b>Pr =</b>	<b>0.0003</b>	<b>0.007</b>	<b>0.0004</b>	<b>0.002</b>	<b>0.011</b>

Means with the same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

## (B):

Species	Spacing (m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	100.85 a 82.69b	96.75 a	113 a	109.42 a	64.67 a
<i>M.mallofolia</i>	81.92b	83.39b	83.33bc	105.42 a	33.75b
<i>M. acidosa</i>	65.55b	63.82 c	73.76c	100ac	52.50 a
<i>M.mesozyga</i>	47.75 C	89.57 ab	95.67 b	83.57b	36.00b
<i>M. tiliaefolia</i>		51.89d	45.91 d	64.71 C	34.20b
<b>Pr =</b>	<b>0.0003</b>	<b>0.007</b>	<b>0.0004</b>	<b>0.002</b>	<b>0.011</b>

Means with the same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

(C): Third measurement (3-month old plants)

Species	Spacing(m)									
	Spacing (1) 0.6x0.75m		Spacing (2) 05x1m		Spacing (3) 1x1m		Spacing (4) 1.5x1m		Spacing (5) 2x2m	
<i>M. alba</i>	132.53	a	128.93	a	148.47	a	143.33	a	115	a
<i>M.mallotfolia</i>	101.55	b C	117.50	a	128.00	ab	151.25	a	115	a
<i>M. acidosa</i>	115.23	b	118.04	a	124.55	b	123.64	ab	110a	
<i>M.mesozyga</i>	96.43	C	92.50b		108.13	b	98.75	cb	103.75	a
<i>M. tiliaefolia</i>	53.95	d	58.52b		57.10c		76.71 c		89.00	a
<b>Pr =</b>	<b>0.0001</b>		<b>0.0001</b>		<b>0.0001</b>		<b>0.002</b>		<b>0.31</b>	

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

(D): Fourth measurement (3-month old plants)

Species	Spacing(m)									
	Spacing (1) 0.6x0.75m		Spacing (2) 05x1m		Spacing (3) 1x1m		Spacing (4) 1.5x1m		Spacing (5) 2x2m	
<i>M. alba</i>	163.35	a	173.68	a	188.16	a	189.27	a	77.80	a b
<i>M.mallotfolia</i>	147.43	a b	150.41	b	150.25	b	167.18	a b	55.13	b
<i>M. acidosa</i>	135.64	b	152.39	a b	161.33	b	189.70	a	45.00	b
<i>M.mesozyga</i>	134.14	b	98.69	c	144.69	b	152.13	b	104.83	a
<i>M. tiliaefolia</i>	65.90	c	64.58	d	76.83	c	114.71	c	78.17	a b
<b>Pr =</b>	<b>0.0001</b>		<b>0.0001</b>		<b>0.0001</b>		<b>0.002</b>		<b>0.31</b>	

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

#### Number of leaves within spacing

Similar to height growth, the number of leaves was significantly different between families within spacing and measurement (Table 5 a, b, c and d). The number of leaves of

*M. alba* was higher than the other species in each of the spacing and measurement, while *M. tiliaefolia* gave the least number of leaves (Table 5 a, b, c and d).

**Table (5)**  
Number of leaves for the five *Morus* species and spacing (m).

(A): First measurement (1 month old plants):

Species	Spacing(m)									
	Spacing (1) 0.6x0.75m		Spacing (2) 05x1m		Spacing (3) 1x1m		Spacing (4) 1.5x1m		Spacing (5) 2x2m	
<i>M. alba</i>	70.86	a	51.25	a	87.00	a	85.67	a	50	a
<i>M.mallotfolia</i>	42.31	a	41.15	a	59.10	b	35.33	b	32.6	a
<i>M. acidosa</i>	35.37	b	29.13	c b	31.25	c d	64.31	a b	16.75	a
<i>M.mesozyga</i>	35.36	b	33.50	c b	51.25	c b	35.83	b	26.20	a
<i>M. tiliaefolia</i>	27.85	b	26.67	c	22.00	d	36.67	b	18.88	
<b>Pr =</b>	<b>0.0001</b>		<b>0.0002</b>		<b>0.0001</b>		<b>0.002</b>		<b>0.09</b>	

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(B): Second measurement (2 month old plants):**

Species	Spacing (m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	159.27 a	117.96 a	273.80 a	268.33 a	68.33 a
<i>M.mallotfolia</i>	129.61 a	130.66 a	170.08 b	247.70 a	31.13 b
<i>M. acidosa</i>	102.68 b	130.29 a	208.60	232.67 a	29.20 b
<i>M.mesozyga</i>	68.77 c	54.59 b	84.38 c	144.00 b	45.00 a b
<i>M. tiliaefolia</i>	30.44 c	37.73 b	31.09 c	47.43 c	23.40 b
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.013</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(C): Third measurement (3 month old plants):**

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	169.62 a	183.39 a	334.37 a	359.22 a	841 a
<i>M.mallotfolia</i>	140.00 a b	194.87 a	204.90 b	241.00 b	220.50 b c
<i>M. acidosa</i>	117.59 b	143.40 a	234.00 b	399.00 a	406.80 b
<i>M.mesozyga</i>	81.95 c	53.08 b	115.56 c	129.00 c	238.00 b c
<i>M. tiliaefolia</i>	38.42 d	39.88 b	39.83 d	54.29 c	107.20 c
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(D): Fourth measurement (4 month old plants):**

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	229.26 a	274.30 a	442.74 a	640.27 a	122.80 a
<i>M.mallotfolia</i>	193.75 a b	222.32 a	248.58 b c	440.00 b	606.00 a
<i>M. acidosa</i>	164.98 b	219.22 a	428.87 b	652.50 a	456.70 a
<i>M.mesozyga</i>	110.90	79.63 b	168.94 c	266.13 b	220.67 a
<i>M. tiliaefolia</i>	75.00 d	40.73 b	40.25 d	85.86 c	101.00 a
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.26</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**Number of branches**

The species effect was significant similar to number of leaves and height growth. Large variation between species exists

within each spacing and measurement (**Table 6 a, b, c and d**). The number of branches was higher for *M. alba* and less for *M. tiliaefolia*.



**Table (6)**  
Number of branches for the five *Morus* species tested at five spacing (m).

**(A): First measurement (1 month old plants):**

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	7.81 a	5.00 a b	7.85 a	10.42 a	6.16 a
<i>M.mallotfolia</i>	5.58 b	5.15 a b	4.66 b	4.75 b	10.25 a
<i>M. acidosa</i>	4.64 b c	5.60 a	3.74 c b	5.08 b	4.60 a
<i>M.mesozyga</i>	3.74 c	4.50 b	1.62 c	3.67 b	2.60 a
<i>M. tiliaefolia</i>	3.50 c	3.60 b	2.59 c b	7.44 a b	2.50 a
<b>Pr =</b>	<b>0.0001</b>	<b>0.04</b>	<b>0.0001</b>	<b>0.02</b>	<b>0.32</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(B): First measurement (2 month old plants):**

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	12.20 a	11.39 a	25.55 a	24.59 a	13.33 a
<i>M.mallotfolia</i>	12.04 a	11.86 a	16.67 b	23.25 a	6.13 b
<i>M. acidosa</i>	10.45 a	13.71 a	14.67 b	24.75 a	4.40 b
<i>M.mesozyga</i>	5.89 b	5.00 b	6.75 c	12.00 b	8.50 b
<i>M. tiliaefolia</i>	3.00 c	3.89 b	3.10 c	4.71 c	2.40 b
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.003</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(C): Third measurement (3 month old plants):**

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	13.03 a	14.54 a	32.68 a	40.22 a	40.5 a
<i>M.mallotfolia</i>	11.91 a	15.75 a	19.82 b	25.46 b	15.75 b
<i>M. acidosa</i>	10.79 a	12.10 a	23.47 b	41.25 a	32.25 a b
<i>M.mesozyga</i>	6.35 b	4.75 b	8.25 c	12.25 c	18.50 a b
<i>M. tiliaefolia</i>	3.90 b	3.88 b	3.33 c	4.43	8.80
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.05</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

**(D): Second measurement (2 month old plants):**

Species	Spacing(m)				
	Spacing (1) 0.6x0.75m	Spacing (2) 05x1m	Spacing (3) 1x1m	Spacing (4) 1.5x1m	Spacing (5) 2x2m
<i>M. alba</i>	14.29 a	20.14 a	37.11 a	46.64 a	15.20 a
<i>M.mallotfolia</i>	12.53 a	17.44 a	18.08 b c	29.49 b c	7.38 a
<i>M. acidosa</i>	12.19 a	14.44 a	26.46 b	41.60 a b	3.67 a
<i>M.mesozyga</i>	8.53 b	5.75 b	11.63	16.94 c d	14.33 a
<i>M. tiliaefolia</i>	3.53	3.92 b	3.33 d	4.86 d	6.66 a
<b>Pr =</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.20</b>

Means with same letter in the same columns are not significantly different at 0.05 level using Duncan multiple tests.

#### IV. DISCUSSIONS

The variation in survival percentage, between the five tested species after 2, 3 and 4 months in the field, within each

spacing, reflects the difference in adaptability. The high survival of *M. mesozygia* (100% in most of the spacing) indicates its tolerance to the planting conditions. It is introduced in Sudan, as ornamental species long before the others. This is result in line with [15] who stated that survivability is a capacity of plant withstand and survives under varied climatic condition and supported by [16] studies on survival percentage of mulberry varieties performance and coincided with [7] on survival rate beside [17].

The study showed significant species variation, in all growth parameters, for the original growth. The same result was reported by [15] who stated a significant variation on survival and growth of mulberry. The species ranking in yield of leaf and branch (number and weight) in the original and coppice plantation was in the following order: *Morus alba*, *M. maiotfolia*, *M. acidosa*, *M. mesozygia*, and *M. tiliaefolia* (from high to low). [18] Organize the top ranking species as *M alba* and reported it as good parent type with wide adaptability and stress resistance, noted for its high leaf yield, good leaf quality, with protein content of 24.5%. This study also identified *M. alba* as a candidate species, for establishment of mulberry plantation in the Groves land of the Sudan, to obtain high growth, however, *M. mesozygia* is the candidate if survival is included in the selection criteria.

These results indicate the importance of species selection, in introducing mulberry plants as exotics to the Sudan. For future large operational planting programs, care should be taken, in matching the species with the site this supported by [6]. The high productivity of any species needs further check by the quality and quantity of silk. The growth of all tested species in this study in terms of leaf productivity was higher than that reported by [19].

The high survival of the five tested species, in the first and second month after planting in all planting spaces, showed that competition is minimal at the early establishment stages. However, the effect of spacing was pronounced in the third and fourth months. Wider spacing showed high survival (spacing 1 x 1m, 1.5 x 1m) than smaller spacing (spacing 0.6 x 0.75m, 0.5 x 1m). This result is opposite to what was reported by [6] who stated 60x60cm spacing yield higher leaf than 150x150cm of five tripods mulberry varieties, but found leaf quality was better in spacing 150x150cm. However, [13] found the same result on growth and yield of mulberry.

Leaves and branches growth was not affected by spacing in the first month; the effect became clearer with time. The high number and weight of leaves and branches per plant at the wider planting space (1.5 x 1m and 1 x 1m) compared to those of narrow planting space (0.6 x 0.75 and 0.5 x 1m) indicates the effect of competition on foliage yield and growth. The opposite result was reported by [10] and [12] who stated that the average leave fall percentage in S1635 was 31% (60 x 60 cm) spaced plantation and it goes up to 33% under close planting system (60 x 10 cm). The also opposite to the findings reported by [20] and [21] who obtained ,high leaf yield, in spacing 60x60cm.

The spacing of 1 x 1m and 1.5 x 1m are suitable, for the grove (alluvial soil) conditions in Sudan, for high survival and foliages yield. Similar recommendation were made by [9] reported spacing of 1m x 1m in Islamabad (1 x 1m) and [11] reported spacing of 1.5m x 1m in Brazil (1.5 x 1m).

The spacing between plants was found to be an important factor in the survival and growth. The spacing of 1 x 1m and 1 x 1.5m was found to be the suitable one between the tested spacing for high survival, growth and yield per ha.

## V. CONCLUSIONS

From the results of this study and the observations during the experiment, the study showed significant correlation between spacing ,leave yield and survivability of five tested *Morus* species. The high yield obtained in spacing 1x1m and 1x1.5 m. The study concluded that, the spacing 1x1 m and 1x1.5 m are suitable, for general operational planting, for high yield per unit area in Grove land in Sudan . Further studies should be applied, on testing the effect of spacing, on cocoon quality and quantity produced by silkworms, rearing on leaf collect from different spacing. This study will help in enhancing and encouraging, sericulture and other agricultural investment in the Sudan, particularly in rural areas, to generate incomes, for farmers.

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