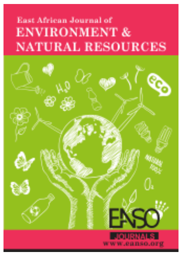

East African Journal of Environment and Natural Resources
eajenr.eanso.org
Volume 5, Issue 2, 2022
Print ISSN: 2707-4234 | Online ISSN: 2707-4242
Title DOI: https://doi.org/10.37284/2707-4242

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Effects of Negarim Micro Catchment on Growth and Survival of Two Provenances of Moringa oleifera Under Different Spacing in a Semi-Arid Area of Kitui County, Kenya

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Article DOI: https://doi.org/10.37284/eajenr.5.2.927

Date Published:

04 November 2022

Keywords:

Height, Root Collar Diameter, Gede Provenance, Machakos Provenance, Negarim Micro Catchment

ABSTRACT

Kenya has a large population of multifunctional tree species like Moringa oleifera (Lamark). Two provenances of Moringa oleifera from areas of Gede and Machakos were used in a study to examine how Negarim micro catchment affects their growth and survival traits under various spacings. An experiment was set up in a Randomised Complete Block Design with three replicates. Root collar diameter, branches development, survival rate and increase in height were the variables of interest and data was collected for 16 months (January 2018/April 2019). For Gede provenance under catchment, plant height ranged from 83 to 123 cm, root collar diameter from 1.7 to 2.5 cm, number of branches from 13 to 15, and survival rate of 51 to 74 %. Under no catchment, plant height varied from 127 and 191 cm, root collar diameter between 2.7 and 4.4 cm, number of branches between 15 and 19, and survival rate between 70 and 75 %. The Machakos provenance results under catchment revealed that plant height varied from 62 to 174 cm, root collar diameter ranged from 0.9 to 4.7 cm, the number of branches varied from 8 to 15, and survival rate ranged from 48 to 69 %. Under no catchment, it reached a height of between 43 and 171 cm, root collar diameter between 1.5 and 3.6 cm, 10 to 16 branches, and survivability of between 57 and 78 %. Provenance and Negarim micro catchment had a significant effect on survivability ($p \leq 0.05$), height ($p \leq 0.05$), and branch development ($p \leq 0.05$). The significant differences between plants under Negarim micro catchment were because the catchment provided more moisture advantages to plants than those that were under no catchment. This demonstrates their appropriateness and the possibility of recommending them to be included in tree cultivation systems in the area and other places with comparable climatic circumstances. This research is noteworthy in promoting soil erosion management and environmental preservation by providing information and methods for effectively using runoff in valuable crops/tree production.

APA CITATION

Obala, D., Ng'ang'a, F. M., Kiruki, H., Mutiso, F., & Ndung'u, C. (2022). Effects of Negarim Micro Catchment on Growth and Survival of Two Provenances of Moringa oleifera Under Different Spacing in a Semi-Arid Area of Kitui County, Kenya. *East African Journal of Environment and Natural Resources*, *5*(2), 14-28. https://doi.org/10.37284/eajenr.5.2.927.

CHICAGO CITATION

Obala, Desmond, Felista Muriu-Ng'ang'a, Harun Kiruki, Festus Mutiso and Charles Ndung'u. 2022. "Effects of Negarim Micro Catchment on Growth and Survival of Two Provenances of Moringa oleifera Under Different Spacing in a Semi-Arid Area of Kitui County, Kenya". *East African Journal of Environment and Natural Resources* 5 (2), 14-28. https://doi.org/10.37284/eajenr.5.2.927.

HARVARD CITATION

Obala, D., Ng'ang'a, F. M., Kiruki, H., Mutiso, F., & Ndung'u, C. (2022) "Effects of Negarim Micro Catchment on Growth and Survival of Two Provenances of Moringa oleifera Under Different Spacing in a Semi-Arid Area of Kitui County, Kenya", *East African Journal of Environment and Natural Resources*, 5 (2), pp. 14-28. doi: 10.37284/eajenr.5.2.927.

IEEE CITATION

D. Obala, F. M. Ng'ang'a, H. Kiruki, F. Mutiso, & C. Ndung'u., "Effects of Negarim Micro Catchment on Growth and Survival of Two Provenances of Moringa oleifera Under Different Spacing in a Semi-Arid Area of Kitui County, Kenya", *EAJENR*, vol. 5, no. 2, pp. 14-28, Nov. 2022.

MLA CITATION

Obala, Desmond, Felista Muriu-Ng'ang'a, Harun Kiruki, Festus Mutiso & Charles Ndung'u. "Effects of Negarim Micro Catchment on Growth and Survival of Two Provenances of Moringa oleifera Under Different Spacing in a Semi-Arid Area of Kitui County, Kenya". *East African Journal of Environment and Natural Resources*, Vol. 5, no. 2, Nov 2022, pp. 14-28, doi:10.37284/eajenr.5.2.927.

INTRODUCTION

The increasing human population in high-potential areas has led to the utilisation of marginal lands in semi-arid areas for agronomic purposes (Anschütz *et al.* 2003). Unfortunately, these agronomic activities are limited by the lack of water, high rates of runoff due to torrential rains, and high evapotranspiration rates (CASL, 2006). This necessitates the need for rainwater harvesting (and conservation) if any agriculture has to be practised in these areas (Heluf & Yohannes, 2002). To fully utilise the available water for plant growth, efficient methods of capturing and controlling the water must be used. By adopting the most suitable and integrated systems of production and water harvesting techniques, the livelihoods of small-scale farmers can be improved through proper utilisation of rainfall received in an area (Ibraimo & Munguambe, 2007). Some methods of integrated water use include water harvesting, supplementary irrigation, specific irrigation, and soil and water conservation practices (Molden *et al.*, 2010)

Food tree species are important in the diets of the people, as well as providing cash income from the sale of non-timber products (Larwanou *et al.* 2014). *Moringa oleifera* a multipurpose tree/shrub species is one such tree. It is considered a potential source of dietary calcium in many developing countries (Issa, 2012) and generally is useful in fighting malnutrition (Thurber & Fahey, 2009). The tree's ideal growth habitats are in both subtropical and tropical climates; with a temperature range of 25 – 35^{0}C, loamy or sandy soils with a pH ranging from 4.5 to 9.0 (Edward *et al.* 2014) and an average of 250 – 3000mm of rainfall per annum (Thurber & Fahey, 2009) but, not in waterlogged sites. Propagation is done through both seeds and stem cuttings (Zaku *et al.* 2015)

An optimum soil-water balance is important in ensuring success in agricultural activities in strained rainfall areas like arid and semi-arid lands (Yue *et*

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

al. 2016). Moisture deficit is among the main environmental factors that hinder the overall growth and development of a plant (Aslam *et al.* 2006). Soil moisture deficiencies occurring at different stages of plant growth are closely related to the development stage of the plant (Jaleel *et al.* 2008), and this can affect the overall plant biomass and its productivity (Araus *et al.* 2002). Frequent droughts and population growths are common phenomena in many African countries that result in a decrease in the volumes of water that is available for agricultural practices (Macedonio *et al.* 2012). This, therefore, calls for initiating water-efficient agricultural practices that preserve rainfall water to ensure increased soil-water content, hence, reducing its demand and supply gap.

The introduction of drought-resistant plant species can improve agricultural production (Ghoulam *et al.* 2002). Negarim micro catchment (NMC) is among the rainwater harvesting techniques employed for harvesting rainwater in trees growing in semi-arid areas. These are diamond-shaped basins constructed with small bunds of earth that are meant to concentrate water at the infiltration pit, which is usually at the lowest corner of the Negarim unit. The infiltration pit can either be designed in square or circular form, with its size varying as per the size of the catchment area in use (Kahinda *et al.* 2007). These units are mostly used in raising trees and soil conservation and are suitable for small–scale production in areas that are moisture deficient (Dauda & Baiyeri, 2009)

Limited studies on provenance trials, use of micro catchments and Spacing have been undertaken, especially on *Moringa oleifera*. More data is, therefore, required on provenance trials, use of micro catchments and Spacing on *Moringa oleifera* and its ability to thrive under different agricultural systems, extensive and commercial plantings, especially under semi-arid lands which are increasingly experiencing drought conditions and increase in population. Considering that water scarcity for agricultural production will continue to be a challenge in these areas, there is a need to explore combinations of water-saving technologies and plants which give optimum production results in arid conditions. This will form the basis for recommendations for extensive production by local farmers in Kenya (Scott & Sullivan, 2007). Therefore, the main objective of this study was to determine the effects of NMC on the growth and survival characteristics of two provenances of *M. oleifera* under different Spacing in Kitui County; while hypothesising that there were no differences among parameters of interest.

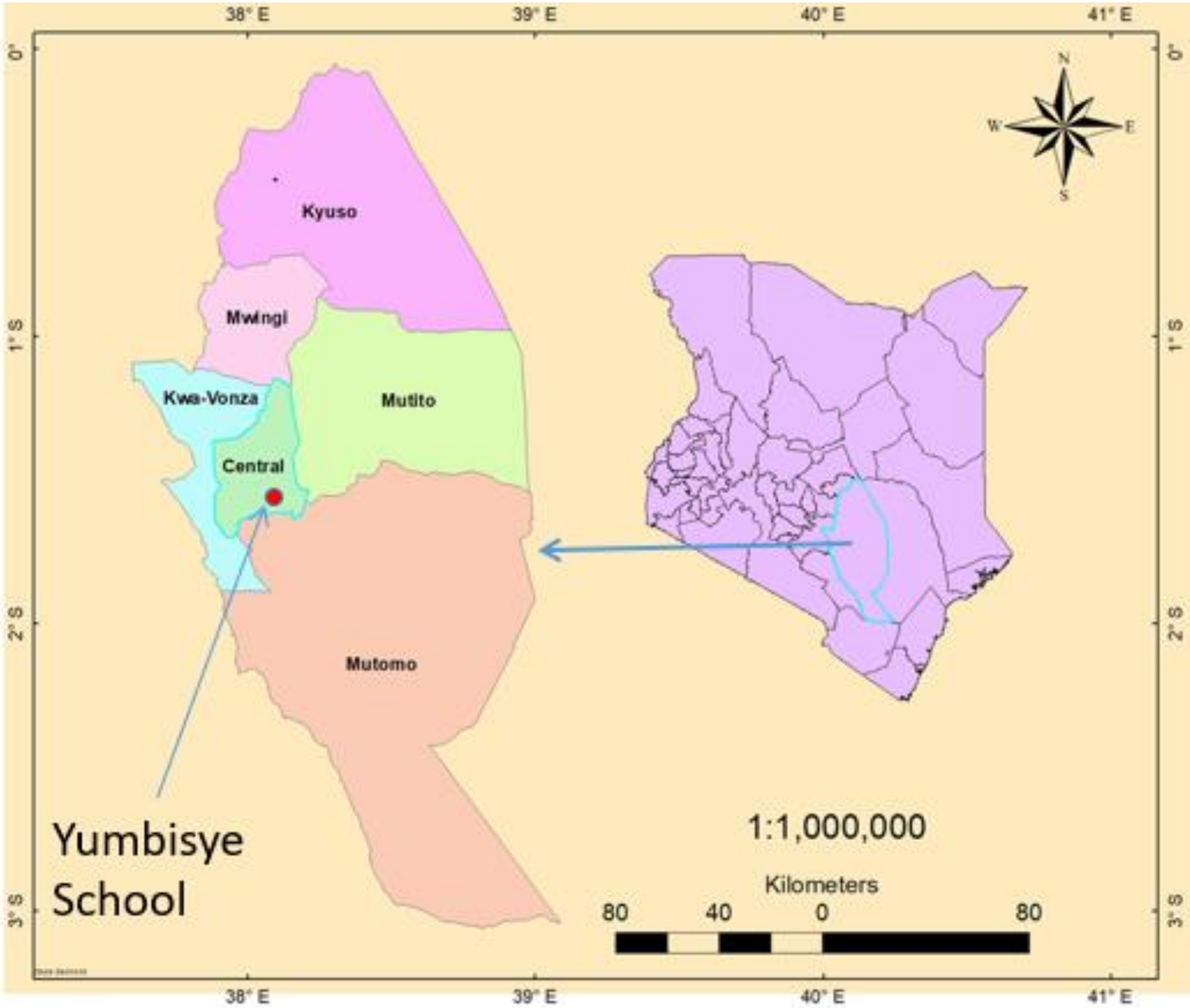
MATERIALS AND METHODS

Study Area

The experiment was set out on a farm at Yumbisye Secondary School (latitude 38.01057 E and longitude 1.39988 S) in Kitui Central Sub-County. The climate of this location varies between semi-arid and semi-humid and receives 1000 mm of rainfall annually, with 40 percent of overall dependability. The major rainy season, from April to May, is seeing a general reduction, while the brief rainy season, which lasts from September to December, is seeing a general uptick. The months of January through March and June through September tend to be dry. The yearly mean highest temperature ranges from 28^0C to 32^0C, while the mean lowest temperature ranges from 22^0C to 28^0C (Oremo, 2013). The farm's terrain is primarily level and slowly slopes to the west, and the soils are mainly sandy.

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

Figure 1: The study area



Experimental Design

A 2 × 2 × 3 factorial Randomised Complete Block Design design was used for the experiment. Two levels of *Moringa oleifera* provenances; that were sourced from Gede and Machakos, two levels of water harvesting; under Negarim micro catchment and under no catchment as control and three spacing levels 100 cm × 100 cm, 150 cm × 150 cm M, and 200 cm × 200 cm were merged into 12 treatments, randomly assigned, and simulated three times. Seedlings were initially planted and raised in a nursery before being transferred to the experimental plots for measurements to be taken.

Nursery's activities began with the acquisition of seeds for two provenances of *Moringa oleifera* - in areas of Gede and Machakos. Cleaning of the seeds was done before sorting them out on the basis of their size and colour. Those that were larger than 1 centimetre in diameter with grey/white colour were selected to be planted. In November 2018, a seedlings nursery was established at the Botanical Garden of South Eastern Kenya University, located some 30 kilometres from the research site. Thirty-six randomly set plots were established, where one provenance had 18 plots, and each plot had 20 pots with a diameter of 12 centimetres and 18 centimetres height. The pots were arranged 15 centimetres from each column and row

In the field, a block of land was cleared of all the vegetation, cultivated with a tractor, and levelled to a fine tilth before being divided into 3 equal sub-blocks while considering the slope of the land. Each sub-block was divided into 12 plots and each plot

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was considered an experimental unit. The treatments were randomised within the three sub-blocks and replicated three times. In December 2018, 16 seedlings were transplanted on each plot in line with targeted treatments of Spacing, provenance and Negarim micro catchment. For treatments under catchment, a Catchment to Cultivation Area (C: CA) ratio of 3:1 was considered for all the different Spacing. The catchment area was deliberately left uncultivated, purposely to harvest and direct runoff to the cultivation area, where plants were established.

Data Collection and Analysis

After one and a half months of transplanting, four plants were selected randomly from each plot and tagged for monitoring. As the plants grew, parameters of interest, namely height, branch development, root collar diameter and survival rate, were monitored and with measurements taken once a month for 16 months. Height measurements were taken by use of a graduated meter rule from the base to the topmost bud of the main shoot, and root collar diameter was measured by a Vernier calliper, while primary branching and all surviving plants on the plot were manually counted.

The data was cleaned and analysed by comparing the mean growth of the experimental units under the Negarim micro catchment and their control under different plant spacing. The data was analysed using a three-factor Analysis of Variance at a 95% confidence level and the differences in the treatments were tested using the F test at a *p*-value of 0.05.

RESULTS

Under Normal Conditions

Increase in Plant Height

It was observed that all of the plants' heights increased steadily during the early phases of growth. As displayed below in *Figure 2(a)*, Machakos provenance at 150 cm × 150 cm spacing level achieved the lowest mean increase in height, whereas Gede provenance at 200 cm × 200 cm spacing level had the greatest mean average height growth. Under 100 cm × 100 cm spacing level, Machakos' provenance had the greatest mean, while Gede provenance had the lowest mean. Under 150 cm × 150 cm spacing level, the mean was highest for the Gede provenance and lowest for the Machakos provenance. Under 200 cm × 200 cm spacing level, the greatest growth mean was found in the Gede provenance, while the lowest was found in the Machakos provenance. However, at the 5 % level of significance, there were no differences between the provenances at the various spacing levels because ($p > 0.05$).

Root Collar Diameter

The two provenances' root collar diameter growth rates were quite similar. According to *Figure 2(b)* below, Machakos provenance at 150 cm × 150 cm spacing level had the lowest root collar diameter, whereas Gede provenance at 200 cm × 200 cm spacing level had the greatest root collar diameter. Machakos provenance had the highest mean and Gede provenance had the lowest mean at a spacing level of 100 cm × 100 cm. Gede provenance had the greatest mean, while Machakos provenance had the lowest mean at a spacing level of 150 cm × 150 cm. Gede provenance had the highest growth mean and Machakos provenance had the lowest under a spacing level of 200 cm × 200 cm. However, at the 5 % level of significance, there were no differences between the provenances at the various spacing levels because ($p > 0.05$).

Branch Development

The outcomes of branch development have shown a similar pattern, as seen below in Figure 2(c). Machakos provenance at 150 cm × 150 cm spacing level had 10 branches, compared to 19 branches for Gede provenance at 100 cm × 100 cm spacing level, 150 cm × 150 cm branches for Gede, and 200 cm × 200 cm branches for Gede. Due to the severe drought that was experienced, the number of branch developments stalled after six months, slowing the rate of growth. Machakos provenance developed 19 branches under the spacing level of 100 cm × 100 cm, while Gede provenance had 15 branches. Gede provenance developed 19 branches, whereas Machakos provenance had 10 branches under the spacing limit of 150 cm × 150 cm. Under a spacing level of 200 cm × 200 cm, Gede provenance has 19 branches as opposed to 16 branches for Machakos

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

provenance. However, at the 5 % level of significance, there were no differences between the provenances at the various spacing levels because (*p* > 0.05).

Rate of Survival

The percentage of *Moringa oleifera* in Figure Figure 2(d) below depicts a quite comparable trend for the survival rate of the two provenances. The number of surviving plants in the Machakos provenance at 100 cm × 100 cm spacing level was the greatest at 77.5%, while the number of surviving plants in the Machakos Provenance at 150 cm × 150 cm spacing level was the lowest at 57.4%. Gede provenance had 70.3% of the total under the spacing threshold of 150 cm × 150 cm, whereas Machakos provenance had 57.4%. Gede provenance at a spacing level of 200 cm × 200 cm achieved the greatest survival rate mean at 75.4% under the spacing level of 200 cm × 200 cm, whereas Machakos provenance had 59.2%. The plants that recovered after wilting were included in the research. However, at the 5% level of significance, there were no differences between the provenances (*p* > 0.05).

Figure 2a: Plant height

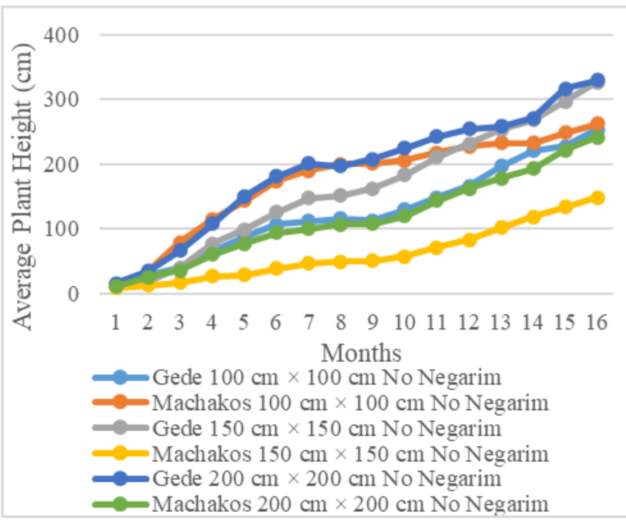


Figure 2b: RCD

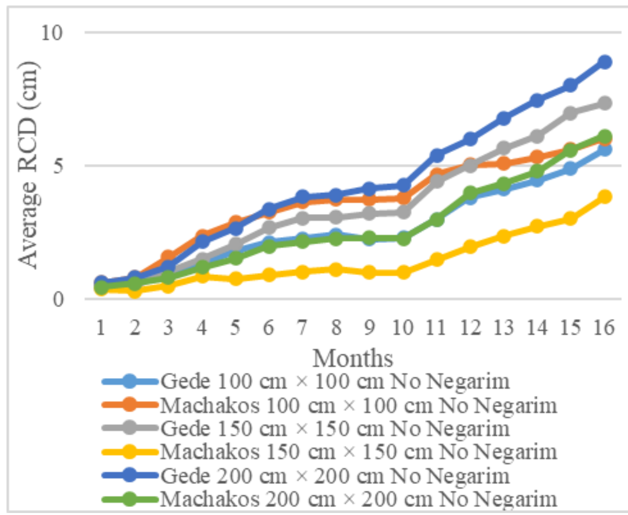


Figure 2c: Branch development

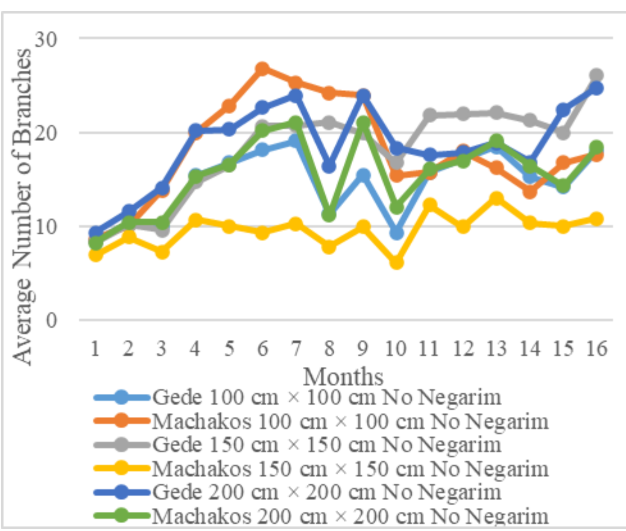
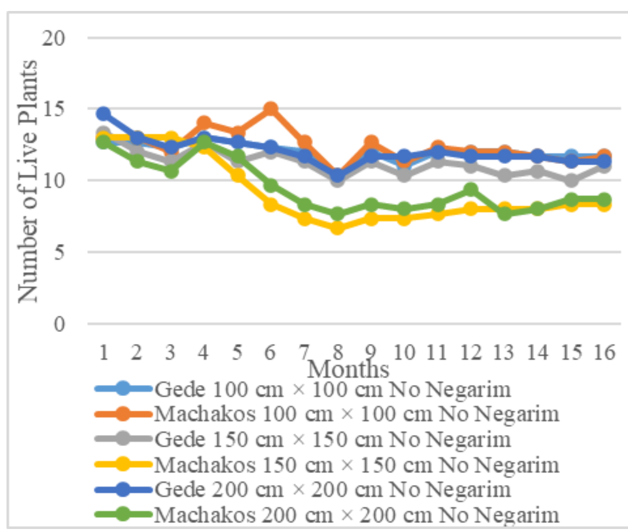


Figure 2d: The survival rate



Article DOI: https://doi.org/10.37284/eajenr.5.1.829

Under Negarim Micro Catchment Conditions

Plant Height

It was observed that all of the plants' heights increased steadily during the early phases of growth. A fairly similar trend was observed when comparing the mean growth in height between the two provenances, as shown in Figure 3(a) below. The Machakos provenance at 150 cm × 150 cm spacing level had the highest mean growth in the height of 243 cm, while the Machakos provenance at 100 cm × 100 cm spacing level had the lowest mean growth in the height of 43 cm, Gede provenance had a mean of 83 cm under the spacing level of 100 cm × 100 cm, while Machakos provenance had a mean of 43 cm. Gede provenance had a lower mean of 120 cm under the spacing level of 150 cm × 150 cm compared to Machakos provenance's mean of 243 cm. Machakos provenance at 200 cm × 200 cm spacing level acquired a growth mean of 171 cm, while Gede provenance had a lower mean of 123 cm. However, at the 5 % level of significance, there were differences between the provenances at the various spacing levels because ($p > 0.05$).

Root Collar Diameter

Similar tendencies in the root collar diameter growth were seen in the two provenances. As indicated in Figure 3(c) below, Machakos Provenance at 100 cm × 100 cm spacing level had the lowest mean average growth of 1 cm, while Machakos Provenance at 150 cm × 150 cm spacing level had the greatest mean average growth of 4.7 cm. Gede provenance had a greater mean of 1.74 cm at 100 cm × 100 cm spacing level, while Machakos provenance had a lower mean of 1 cm. Under a spacing level of 150 cm × 150 cm, the mean for the Machakos provenance was greatest at 4.7 cm, whereas the mean for the Gede provenance was the least 2.4 cm. Machakos provenance achieved a greater expansion mean of 3.5 cm under a spacing level of 200 cm × 200 cm, but Gede provenance produced a smaller mean of 2.5 cm. Nevertheless, at the 5% level of significance, there were no substantial differences across the provenances ($p > 0.05$).

Branch Development

As depicted in Figure 3(b) below, the two provenances' tree primary branch development followed a similar pattern. During the experiment, Machakos provenance at 150 cm × 150 spacing level recorded the least mean number of branches at 8, whereas Machakos provenance at 100 cm × 100 cm spacing level had the greatest mean number of branch development at 21 branches. Gede provenance had a higher mean of 13 at 100 cm × 100 cm spacing level, while Machakos provenance had a lower mean of 8. Machakos provenance had a mean of 21 under the spacing level of 150 cm × 150, while Gede provenance had a mean of 14, which was lower. Machakos provenance attained a higher mean of 16 branch development under the spacing level of 200 cm × 200 cm, while Gede provenance achieved 15 branches. However, at the 5 % level of significance, there were no differences between the provenances at various spacing levels because ($p > 0.05$).

Survival Rate

For the two provenances, the survival rate of the plants in the field exhibited a similar pattern. Machakos provenance at 200 cm × 200 cm spacing level, as well as Machakos Provenance at 100 cm × 100 cm spacing level, both saw an anomalous dip during the seventh month. The severe drought that was experienced in the sixth month can be used to explain this. Some of the plants that had experienced withering were able to regenerate. As can be seen below in Figure 3(d), Machakos Provenance at 200 cm × 200 cm spacing level witnessed a minor decline. Machakos provenance showed a greater survival rate at 61.7% under the spacing level of 100 cm × 100 cm, while Gede provenance had a lower survival rate at 51.0%. Gede origin had a greater survival rate at 150 cm × 150 cm spacing, while Machakos provenance had a lower rate at 69.0%. Gede provenance had a greater survival rate of 73.0% under a spacing level of 200 cm × 200 cm, while Machakos provenance had such a lower survival rate of 48.3%. At the 5% level of significance, however, there were no differences across the provenances ($p > 0.05$).

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

Figure 3a: Plant height

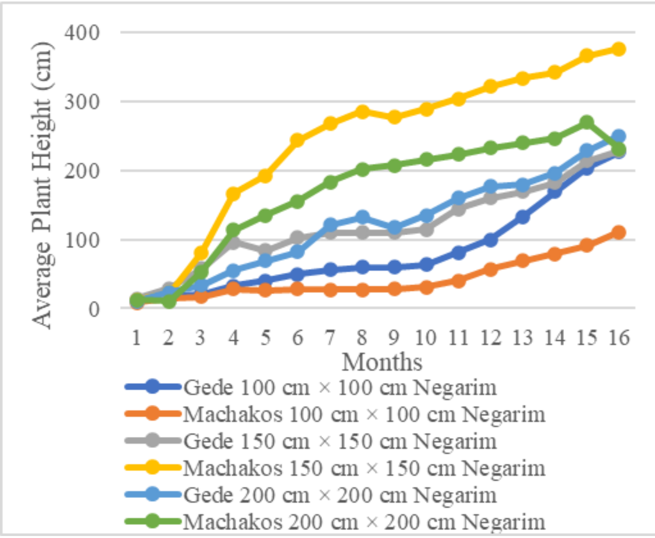


Figure 3b: RCD

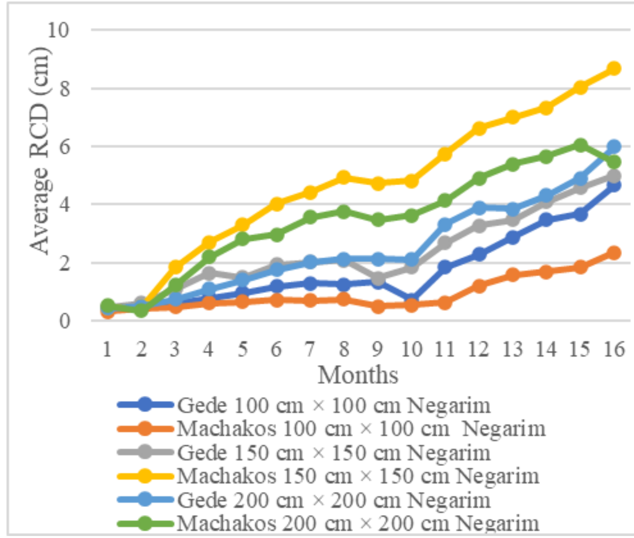


Figure 3c: Branch development

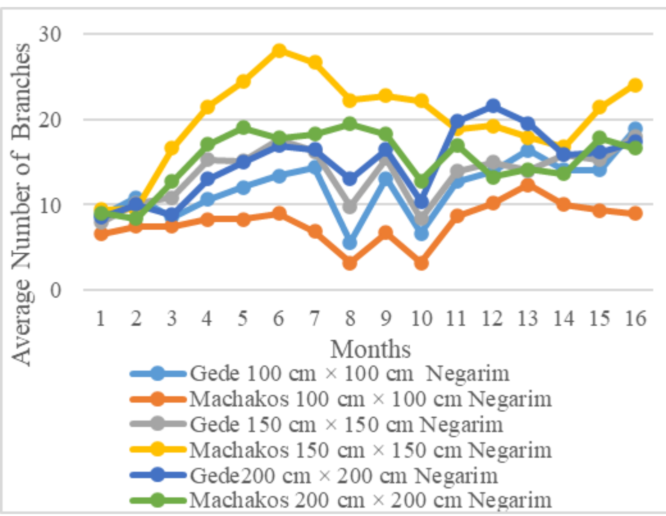
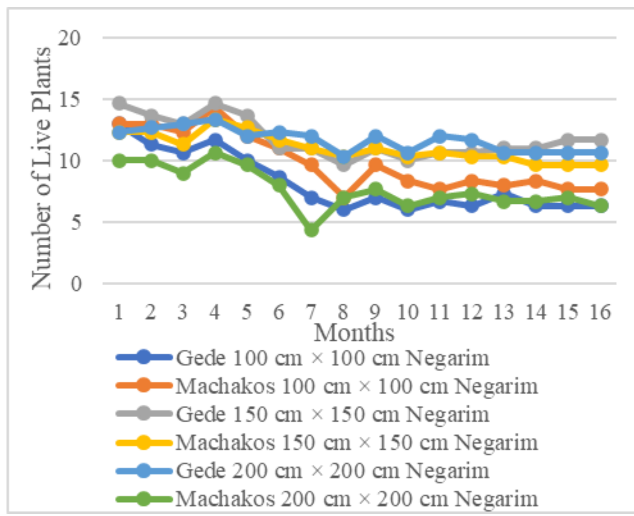


Figure 3d: The survival rate



Moringa oleifera Provenances interaction with Spacing and Catchment Condition

Plant Height

The Machakos provenance had the largest height increase at the 150 cm × 150 cm spacing level and under Negarim micro catchment, whereas Machakos provenance at the 100 cm × 100 cm spacing level under Negarim experienced the lowest growth in height. The Machakos provenance under normal conditions had the highest mean height at 100 cm × 100 cm, while the Machakos provenance under Negarim micro catchment had the lowest. The Machakos provenance had the largest growth mean at the 150 cm × 150 cm spacing level, whereas the Machakos provenance under normal conditions had the lowest mean, with the mean height ranging from 62 to 243 cm. The mean height ranged from 117 to 191 cm at a spacing level of 200 cm × 200 cm, with Gede provenance achieving the highest growth mean and Machakos provenance achieving the lowest value. At a 5 % level of significance, there were no significant main effects of Spacing, provenance, and Negarim micro catchment on plant height. However, as indicated below in *Table 1*, there was a significant effect on height, with the provenance and Negarim micro catchment interaction (p = 0.025).

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Table 1: ANOVA of plant height under various spacing and catchment conditions

Source of variation	d.f.	s.s.	m.s.	F	P. value.
Rep stratum	2	93188	46894	8.42	2
Provenance	1	2858	2858	52	0.480
Spacing	2	25252	12626	2.28	0.126
Negarim	1	2503	2503	0.45	0.508
Provenance.Space	2	4538	2269	0.41	0.669
Provenance.Negarim	1	32269	32269	5.83	0.025*
Spacing.Negarim	2	2436	1218	0.22	0.804
Provenance.Spacing.Negarim	2	33881	16940	3.06	0.067
Residual	22	121747	5534		
Total	35	318673	318673		

Root Collar Diameter

Machakos provenance at 150 cm × 150 cm spacing level and under Negarim micro catchment had the largest average root collar diameter, whereas Machakos provenance at the spacing level of 100 cm × 100 cm under catchment had the smallest. The mean root collar diameter varied between 0.93 and 3.63 cm at a spacing level of 100 cm × 100 cm, with Machakos provenance under normal circumstances attaining the greatest mean and Machakos provenance under Negarim micro catchment obtaining the lowest mean expansion. The mean root collar diameter varied from 1.45 to 4.69 cm at a spacing level of 150 cm × 150 cm, with Machakos provenance under Negarim micro catchment achieving the greatest mean and Machakos provenance under normal circumstances achieving the lowest root collar diameter mean. The mean root collar diameter expansion varied from 2.5 to 4.4 cm at a spacing level of 200 cm × 200 cm, with Gede provenance under normal circumstances obtaining the greatest mean and Gede provenance under Negarim micro catchment achieving the lowest mean. Nevertheless, at a 5 % level of significance, there were no significant main effects of Spacing, provenance, and catchment on root collar diameter. No significant interaction effects of experimental factors on root collar diameter were observed (p = 0.064), as shown below in *Table 2*.

Table 2: ANOVA of RCD under various spacing and catchment conditions

Source of variation	d.f.	s.s.	m.s.	F	P. value.
Rep stratum	2	64.645	32.322	9.09	
Provenance	1	0.354	0.354	0.1	0.755
Spacing	2	38.757	19.378	5.45	0.012
Negarim	1	0.186	0.186	0.05	0.821
Provenance.Space	2	8.955	4.478	1.26	0.303
Provenance.Negarim	1	13.488	13.488	3.79	0.064*
Spacing.Negarim	2	0.064	0.032	0.01	0.991
Provenance.Spacing.Negarim	2	23.552	11.776	3.31	0.05
Residual	22	78.195	3.554		
Total	35	228.196			

Branch Development

Machakos provenance under Negarim micro catchment, at 150 cm × 150 cm spacing level had the maximum mean number of branches, whereas Machakos provenance at 100 cm × 100 cm spacing level and under Negarim micro catchment had the lowest average number of branch development as displayed below in Table 3. The mean number of branches developed at 100 cm × 100 cm spacing levels ranged from 8 to 19, with Machakos provenance under no catchment achieving the greatest mean and Machakos provenance under Negarim micro catchment achieving the lowest

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

number. The mean range of branches that developed was between 10 to 21 at a spacing level of 150 cm × 150 cm, with Machakos provenance under catchment achieving the greatest mean. At 200 cm × 200 cm spacing level and under no catchment, the average number of branch development varied from 15 to 19; Gede provenance achieved the greatest growth mean as contrasted to the Gede provenance under catchment, which achieved the lowest as the mean. Nevertheless, at a 5 % level of significance, there were no significant main effects of Spacing, provenance, and Negarim micro catchment on branch development. However, there was a significant effect on provenance and Negarim micro catchment interaction on branch development at a 5 % level of significance (*p* = < .001)

Table 1: ANOVA of branch development under various spacing and catchment conditions

Source of variation	d.f.	s.s.	m.s.	F	P. value.
Rep stratum	2	368.39	184.19	12.87	
Provenance	1	0.44	0.44	0.03	0.862
Spacing	2	67.56	33.78	2.36	0.118
Negarim	1	5.44	5.44	0.38	0.544
Provenance.Space	2	4.22	2.11	0.15	0.864
Provenance.Negarim	1	277.78	277.78	19.4	<.001*
Spacing.Negarim	2	1.56	0.78	0.05	0.947
Provenance.Spacing.Negarim	2	94.89	47.44	3.31	0.05
Residual	22	314.94	14.32		
Total	35	1135.22			

Survival Rate

In comparison, Gede provenance at a spacing level of 200 cm × 200 cm and under no catchment achieved the highest level of survival rate than Machakos provenance at a 200 cm × 200 cm spacing level and under catchment, which had the lowest survival rate when the experiment was ending. The mean survival rate varied from 51 to 77 % at spacing levels of 100 cm × 100 cm, with Machakos provenance under no catchment obtaining the greatest mean, unlike Gede provenance under catchment, which recorded the lowest survival rate mean. The mean survival rate varied from 57 to 74% at a spacing level of 150 cm × 150 cm, with Gede provenance under catchment attaining the greatest mean and Machakos provenance under normal circumstances obtaining the lowest mean survival rate. The mean survival rate varied from 48.31 to 75.39% at a spacing level of 200 cm × 200 cm, with Gede provenance under normal circumstances reaching the greatest mean and Machakos provenance under catchment obtaining the lowest. Spacing, provenance, and the Negarim micro catchment had no statistically significant major influence on the survival rate at the 5% level of significance. Table 4 below shows the significant relationship between Spacing and the catchment interaction and the final live plants (*p* = 0.033).

Table 2: ANOVA of survival rate under various spacing and catchment conditions

Source of variation	**d.f.**	**s.s.**	**m.s.**	**F**	**P. value.**
Rep stratum	2	2762.6	1381.3	4.23	
Provenance	1	1650.4	1650.4	5.05	0.035
Spacing	2	112.8	56.4	0.17	0.842
Negarim	1	1042.8	1042.8	3.19	0.088
Provenance.Space	2	651	325.5	1	0.385
Provenance.Negarim	1	87.9	87.9	0.27	0.609
Spacing.Negarim	2	2612.8	1306.4	4	0.033*
Provenance.Spacing.Negarim	2	182.3	91.1	0.28	0.759
Residual	22	7185.3	326.6		

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

DISCUSSION

Increases in the height of the provenances varied due to the presence of Negarim micro catchment gave the catchment experimental units extra moisture benefits, unlike those under no catchment. These findings go against those of Gadzirayi et al. (2013), who came to the conclusion that plants grow taller when they are spaced closer to one another owing to competition for light and space, as opposed to when they are spaced farther apart. These findings also go against those of Mahn et al. (2005), who discovered that varied plant spacing had a significant impact on the height of the plant when equated to its biomass output. In contrast to broader Spacing, which saw relatively smaller increases, tighter Spacing led to a greater rate of height growth. Additionally, their findings conflict with the findings of Edward et al. (2014) who noted a notable difference in the height growth of Moringa oleifera provenances planted in two separate areas.

The Negarim micro catchment provided more moisture to the plants compared to plantings under no catchment. Traditionally, it has been believed that trees planted tightly don't produce as many branches as those grown with a wider spacing. However, in this study, competition for growing space and light was not observed. This observation supports the claim made by Mall & Tripathi (2017) that there is not much competition for light when plants are between 1.6 and 2.0 meters tall. Additionally, Amaglo et al. (2006) came to the conclusion that M. oleifera, as a thriving plant crop, exhibited considerable increases in the number of leaves developed and average plant height. They also noted that closely spaced plants experienced faster growth in height when compared to those plants that had been grown under a wide spacing, which had a slightly lower rate of increase in height. The two provenances' capacity to adapt to the unique agronomic and climatic situations where they have been established may have been the reason why there were no statistically significant differences between them. This concurs with the contention of Rodriguez et al. 2018 that the rapid growth of the Moringa oleifera stem demonstrates the plant's capacity to absorb essential growth nutrients and water via the roots.

The root collar diameter of the Moringa oleifera provenances included in this study under the different spacings exhibited significant variations on a plot and no significant differences between the plots. This dispute the findings of Amaglo et al. (2006), who found that widely spaced plants experienced a bigger root collar diameter than those cultivated with a medium spacing and finally those grown with a smaller spacing. This emphasises the significance of choosing the appropriate plant density to produce the highest quality and other product yields of Moringa oleifera under a variety of climatic conditions. The root collar diameter growth results of this investigation, which show no statistical differences between the provenances, are in contrast to those of Gadzirayi et al. (2013), who found significant differences among the provenances they included in their study in Zimbabwe.

Negarim micro catchment system had no discernible impact on either of Moringa oleifera's two provenances. The analysis goes against that of Edward et al. (2006), who found a substantial difference among the provenances examined. The findings of this study are consistent with those of Gadzirayi et al. (2013), who found no significant ($p > 0.05$) interactions between provenance and Spacing on the increase in height, root collar diameter, or branch count in the two provenances of Moringa oleifera included in their study in Malawi. Such results were unforeseen, considering that catchments have long been utilised to increase the amount of water and moisture that is available in ensuring improved plant development and survival rates. Additionally, as mentioned by Edward et al. (2006), considerable discrepancies in the provenances were anticipated due to their variations in tolerance to the predominant climatical circumstances at the research location.

Moringa oleifera provenances included in this research had substantial variations under different Spacing and catchments used, which suggests that plants under catchment were more adaptable because of the additional moisture that the units gathered. As a result, the plants benefited and were more equipped to survive than those outside the catchment. From the first to the third month, the research site experienced some drought, and this caused some plants to wilt and some to die away,

Article DOI: https://doi.org/10.37284/eajenr.5.1.829

but from the fourth month, some were able to regrow. According to Billings (1987), plants are not able to cope with stressful situations to a similar degree or adapt equally when faced with similar environmental changes. This is because they have different abilities to adapt to the prevailing climatic conditions as well as other stressors that affect how they grow and reproduce. According to Raja et al. (2013), Moringa oleifera may thrive in practically all non-waterlogged sandy and loamy soil types. This is because Moringa oleifera is able to withstand dry periods that last six months. Additionally, it can grow in locations with harsh climatic circumstances including water insufficiency, high temperatures, and infertile soils, dissimilar from other forms of vegetation. Research conducted has revealed notable variations in the behaviour of Moringa oleifera provenances as farmed plants. In Tanzania, Edward et al. (2014) found significant variations in the survival rates of two Moringa oleifera provenances that were grown in two locations. According to Edward et al. (2006), such considerable variations in provenances and their capacity to adapt to the prevailing arid conditions in the research sites may have contributed to variations in survival rates.

CONCLUSION AND RECOMMENDATIONS

This study found that there were significant differences in a number of treatment combinations where Negarim micro catchment was a factor. There was a significant effect on provenance and Negarim micro catchment interaction on height; there was a significant effect on provenance and Negarim micro catchment interaction on branch development, and there was a significant effect on Spacing and Negarim micro catchment interaction on the final live plants. However, there were no significant effects of provenance, Spacing and Negarim micro catchment on root collar diameter.

The suitability of the Negarim micro catchment in improving growth characteristics and survival of *Moringa oleifera* was evident in this study. 150 cm × 150 cm can be recommended as the most ideal spacing level for use under Negarim micro catchment to be included in agroforestry farming schemes in the study area and in areas with comparable climatical conditions in enhancing the growth and survival traits of Moringa oleifera. This is important in ensuring increased production and utilisation. Therefore, this study recommends more studies on the effects of Negarim micro catchment and Spacing on seasonal height increases, root collar diameter, branch development and survivability variations of moringa oleifera provenances in an arid and semi-arid area.

ACKNOWLEDGEMENTS

The authors thank South Eastern Kenya University for providing support to undertake this study.

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