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Survival, growth, and leaf area index of annual *Moringa* cuttings (*Moringa oleifera*) in different diameter classes

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Abstract

Moringa oleifera is a fast-growing tree known for its nutritional and medicinal value. The successful establishment and growth of *Moringa* cuttings are crucial for its cultivation and utilization. The diameter of the cuttings can potentially influence their survival, growth, and leaf area index. Understanding the relationship between diameter classes and plant performance can aid in optimizing cultivation practices and improving productivity. This research paper investigates the survival percentage, growth (shoot length and plant height), and leaf area index of annual *Moringa* cuttings (*Moringa oleifera*) in different diameter classes. The study aims to provide insights into the performance and development of *Moringa* cuttings based on their diameter size. The data collected over a period of six months (from 1 month after planting to 6 months after planting) were analysed and compared across the different diameter classes. The highest survival percentage of Annual *Moringa* Cuttings was observed in the 30-35 mm diameter class at 70.83%, while the lowest survival percentage was found in the 55-60 mm diameter class at 48.61%. In terms of the number of leaves, the highest count was recorded in the 30-35 mm diameter class at 37.915, while the lowest count was in the 55-60 mm diameter class at 4.33. The highest shoot length and plant height were observed in the 30-35 mm diameter class at 6MAP, measuring 59.65 cm and 68.750 cm, respectively. Conversely, the lowest shoot length and plant height were found in the 55-60 mm diameter class at 3MAP and 2MAP, measuring 9.89 cm and 19.165 cm, respectively. Lastly, the highest leaf area index was recorded in the 30-35 mm diameter class at 6MAS, measuring 14.27, while the lowest leaf area index was observed in the 55-60 mm diameter class at 2MAS, measuring 2.98. These findings offer valuable insights into the performance of Annual *Moringa* Cuttings across different diameter classes and various parameters.

Keywords: *Moringa oleifera*, diameter class, survival percentage, number of leaves, shoot length, plant height, leaf area index

Introduction

Moringa oleifera, commonly known as the drumstick tree or the miracle tree, is a fast-growing, drought-resistant tree native to the Indian subcontinent. It is widely recognized for its nutritional and medicinal properties, making it a valuable plant for food security and sustainable development. The *Moringa* tree (*Moringa oleifera*) holds immense significance in agroforestry systems due to its multifaceted benefits. Native to the Indian subcontinent, this fast-growing, drought-resistant tree has gained global attention for its nutritional and medicinal properties (Fahey *et al*, 2011) [2]. *Moringa* is rich in essential amino acids, vitamins, and minerals, making it a valuable source of nutrition, particularly in areas with food insecurity. Furthermore, its leaves, pods, and seeds have been utilized in traditional medicine for various ailments. In agroforestry systems, *Moringa* serves as an excellent multipurpose tree, providing shade, improving soil fertility through nitrogen fixation, and acting as a windbreak. Its ability to grow in diverse climates and soil conditions makes it adaptable to different agroecological zones (Anwar *et al*, 2007) [1]. Additionally, *Moringa* has potential for income generation through the sale of its products, such as leaves for tea or powdered supplements. The integration of *Moringa* into agroforestry systems promotes sustainable land management practices, biodiversity conservation, and climate change mitigation (Sileshi, *et al*, 2008) [4]. The survival, growth, and leaf area index (LAI) of *Moringa oleifera* cuttings are important factors to consider when assessing the potential of this tree species for various applications. Understanding the relationship between these parameters and the diameter classes of the cuttings can provide valuable insights into the optimal management practices for the cultivation of *Moringa oleifera*.

Survival refers to the ability of the cuttings to establish themselves and persist in a given environment. It is influenced by various factors such as soil conditions, water availability, and pest infestations. Growth, on the other hand, refers to the increase in size, height, and biomass of the cuttings over time. It is influenced by factors such as nutrient availability, light intensity, and temperature. LAI is a measure of the total leaf area per unit ground area and is an important indicator of the photosynthetic capacity and productivity of the plant.

Several studies have been conducted to investigate the survival, growth, and LAI of *Moringa oleifera* cuttings in different diameter classes. For instance, a study by Mishra *et al.* (2018) [3] examined the effect of different diameter classes (small, medium, and large) on the survival and growth of *Moringa oleifera* cuttings. The results showed that larger diameter cuttings had higher survival rates and exhibited faster growth compared to smaller diameter cuttings. Similarly, another study by Sujatha *et al.* (2019) [5] investigated the relationship between diameter classes and LAI of *Moringa oleifera* cuttings. The study revealed that larger diameter cuttings had higher LAI values, indicating a greater photosynthetic capacity and potential productivity.

Understanding the relationship between diameter classes and the survival, growth, and LAI of *Moringa oleifera* cuttings is crucial for optimizing the establishment and productivity of this valuable tree species. This knowledge can inform farmers, researchers, and policymakers in developing appropriate management strategies and promoting the sustainable cultivation of *Moringa oleifera*.

Materials and Methodology

Study area description

The proposed research experiment was carried out in the Forest Nursery and Research Centre of College of Forestry inside the SHUATS campus which are present in the Prayagraj, UP.

Research Site Location

The research site is located at latitude 25° 24' 42" N and longitude 81° 50' 56" and elevation at 98 m above mean sea level. The average annual temperature experiment site is 25.7 °C this region has a sub-tropical climate prevailing in the South-East part of U.P. with both the extremes in temperature, i.e., the winter and the summer. In cold winters, the temperature sometimes is low as 32 °F in December-January and very hot summer with temperature reaching up to 115 °F in the months of May and June. Frost during winter and hot scorching winds during summer are also common and the average annual rainfall is 981 mm with maximum concentration during July to September months with occasional showers in winters.

These works comprised surveying of *Moringa* trees from South Indian States (Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, Kerala) and selection of phenotypically superior trees through plus trees selection criteria. Plus, trees will be marked in the field and location was recorded with GPS instrument. After surveying, pods/seeds and vegetative propagules was collected from the selected plus trees.

Methodology

Preparation of cuttings: Select healthy and disease-free *Moringa* plants for taking cuttings. Use a sharp and sterilized pruning shears or knife to take cuttings. Take

cuttings from branches that are approximately 25-60 mm in diameter, as per the treatment combinations mentioned. Ensure that each treatment combination has sufficient number of cuttings for replication.

Treatment allocation: Randomly assign each treatment combination to the experimental units (replications). Ensure that each treatment combination has an equal number of replications (3 in this case). Use a completely randomized design (CRD) to allocate the treatments.

Planting and care of cuttings: Prepare a well-drained and nutrient-rich planting medium (such as a mixture of soil, sand, and compost) in pots or trays. Plant each cutting in a separate pot or tray, ensuring that the cutting is inserted vertically and at an appropriate depth (around two-thirds of the cutting should be buried). Water the cuttings immediately after planting and ensure that the planting medium remains moist throughout the experiment. Place the pots or trays in a suitable location with adequate sunlight.

Monitoring and data collection: Regularly monitor the growth and development of the cuttings. Record data on parameters such as survival rate, rooting percentage, number of leaves, shoot length, and root length. Collect data at regular intervals for a specified duration (e.g., 6-8 weeks). **Statistical analysis:** Once the data collection is complete, analyze the data using appropriate statistical methods.

Result and Discussion

Survival Percentage (%) in Different Diameter class of Annual *Moringa* Cuttings (*Moringa oleifera*)

The survival percentage in different diameter classes of Annual *Moringa* cuttings (*Moringa oleifera*) was calculated and pooled data was obtained. The results shown in table 1 are as follows the diameter class with the highest survival percentage was 30-35 mm, with a pooled survival percentage of 72.22% in 2021 and 69.44% in 2022, resulting in a pooled survival percentage of 70.83%. The diameter class with the next highest survival percentage was 25-30 mm, with a pooled survival percentage of 69.44% in 2021 and 66.70% in 2022, resulting in a pooled survival percentage of 68.07%. The diameter class with the lowest survival percentage was 55-60 mm, with a survival percentage of 50.00% in 2021 and 47.22% in 2022, resulting in a pooled survival percentage of 48.61%. The other diameter classes had survival percentages ranging from 63.90% to 58.33%, with the 40-45 mm diameter class having a pooled survival percentage of 63.85%, the 45-50mm diameter class having a pooled survival percentage of 62.50%, and the 50-55 mm diameter class having a pooled survival percentage of 54.17%

Table 1: Pooled Survival Percentage (%) in Different Diameter class of Annual *Moringa* Cuttings (*Moringa oleifera*)

Treatments	2021	2022	Pooled
25-30 mm diameter	69.44	66.70	68.07
30-35 mm diameter	72.22	69.44	70.83
35-40 mm diameter	66.67	65.67	66.53
40-45 mm diameter	63.90	62.89	63.85
45-50 mm diameter	63.89	61.11	62.50
50-55 mm diameter	58.33	50.00	54.17
55-60 mm diameter	50.00	47.22	48.61
F-test	S	S	S
C.D.	15.082	11.593	6.435
SE(m)	4.924	3.785	1.892
SE(d)	6.964	5.353	2.675
C.V.	14.048	66.7	4.309

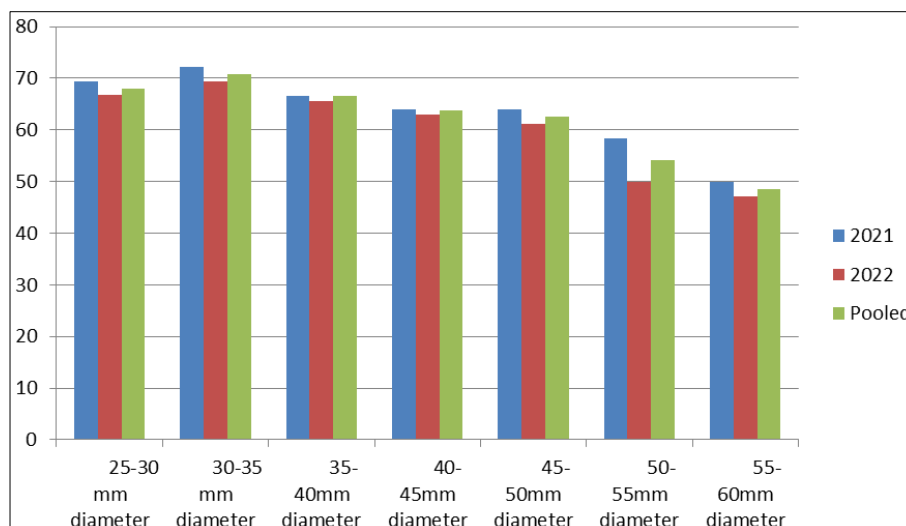


Fig 1: Survival Percentage (%) in Different Diameter class of Annual *Moringa* Cuttings (*Moringa oleifera*) Pooled

Number of leaves in Different Diameter class of Annual *Moringa* cuttings (*Moringa oleifera*)

The number of leaves in different diameter classes of Annual *Moringa* cuttings (*Moringa oleifera*) were measured at various time points. The pooled data for each diameter class shown in table 2 is as follows: The diameter class with a range of 55-60 mm had the highest number of leaves, with a pooled count of 4.777 leaves at 1 month after planting (MAP), 4.33 leaves at 2 MAP, and 4.554 leaves at 3 MAP. This was followed by the diameter class of 50-55 mm, which had a pooled count of 4.79 leaves at 1 MAP, 4.33

leaves at 2 MAP, and 4.56 leaves at 3 MAP. The diameter class with the lowest number of leaves was 45-50 mm, with a pooled count of 4.89 leaves at 1 MAP, 4.45 leaves at 2 MAP, and 4.67 leaves at 3 MAP. This was followed by the diameter class of 40-45 mm, which had a pooled count of 5 leaves at 1 MAP, 4.56 leaves at 2 MAP, and 4.78 leaves at 3 MAP. The number of leaves in the different diameter classes of Annual *Moringa* cuttings ranged from 4.777 leaves to 5 leaves, with the highest count found in the 55-60 mm diameter class and the lowest count in the 45-50 mm diameter class.

Table 2: Number of leaves in Different Diameter class of Annual *Moringa* cuttings (*Moringa oleifera*) Pooled

Treatments	1MAP			2MAP			3MAP			4MAP			5MAP			6MAP		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
25-30 mm diameter	5.24	4.60	4.920	10.1	9.68	9.890	16	15.70	15.850	22.09	21.71	21.900	29.12	28.70	29.12	38.05	37.69	37.870
30-35 mm diameter	5.3	4.70	5.000	10.25	9.68	9.965	16.1	15.72	15.910	22.1	21.65	21.875	29.18	28.80	29.18	38.1	37.73	37.915
35-40 mm diameter	5.11	4.58	4.845	10	9.65	9.825	16	15.67	15.835	22.05	21.67	21.860	29.06	28.67	29.06	38	37.67	37.835
40-45 mm diameter	5	4.56	4.780	9.99	9.44	9.715	16	15.43	15.715	22	21.45	21.725	29	28.43	29	37.9	37.44	37.670
45-50 mm diameter	4.89	4.45	4.670	9.9	9.33	9.615	15.9	15.36	15.630	21.9	21.40	21.650	28.9	28.33	28.9	37.8	37.33	37.565
50-55 mm diameter	4.79	4.33	4.560	9.75	9.22	9.485	15.767	15.23	15.499	21.75	21.23	21.490	28.767	28.23	28.767	37.76	37.23	37.495
55-60 mm diameter	4.777	4.33	4.554	9.7	9.11	9.405	15.71	15.10	15.405	21.7	21.10	21.400	28.72	28.10	28.72	37.7	37.10	37.065
F-test	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
C.D.	1.061	1.084	0.142	1.089	1.064	0.612	1.136	1.136	0.469	1.432	1.109	0.458	1.324	1.159	29.12	1.246	1.117	0.143
SE(m)	0.234	0.303	0.257	0.233	0.282	0.259	0.234	0.288	0.241	0.234	0.288	0.245	0.234	0.288	29.18	0.250	0.288	0.198
SE(d)	0.331	0.428	0.363	0.329	0.399	0.366	0.330	0.407	0.340	0.330	0.407	0.346	0.330	0.407	29.06	0.353	0.407	0.279
C.V.	8.202	11.673	7.633	4.056	5.177	3.778	2.540	3.228	2.168	1.845	2.325	1.593	1.399	1.753	29	1.141	1.331	0.743

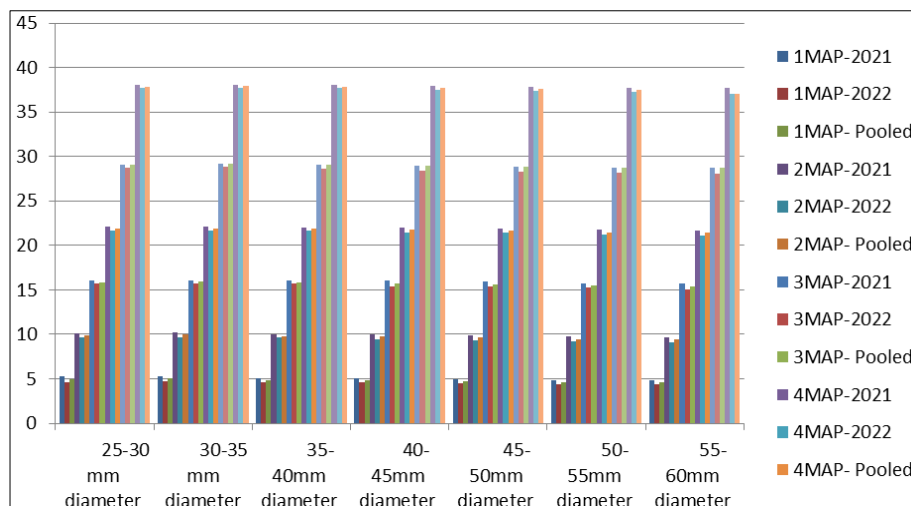


Fig 2: Number of leaves in Different Diameter class of Annual *Moringa* cuttings (*Moringa oleifera*) Pooled

Shoot Length (cm) in Different Diameter Class of Annual *Moringa* cuttings (*Moringa oleifera*)

The shoot lengths (cm) of annual *Moringa* cuttings (*Moringa oleifera*) in different diameter classes were measured at different months after planting (MAP). The data from 2021 and 2022 were pooled for each diameter class. In the 25-30 mm diameter class, the shoot lengths ranged from 10.37 cm to 59.63 cm, with the highest shoot length observed at 6MAP in 2022. For the 30-35 mm diameter class, the shoot lengths ranged from 10.45 cm to 59.65 cm, with the highest shoot length observed at 6MAP in 2022. In the 35-40 mm diameter class, the shoot lengths ranged from 10.45 cm to 59.65 cm, with the highest shoot length observed at 6MAP in 2022. In the 35-40 mm diameter class, the shoot lengths ranged from 10.28 cm to 59.51 cm, with the highest shoot length observed at 4MAP in 2021 and 2022. For the 40-45 mm diameter class, the shoot lengths ranged from 10.24 cm

to 59.46 cm, with the highest shoot length observed at 4 MAP in 2021 and 2022. In the 45-50 mm diameter class, the shoot lengths ranged from 10.22 cm to 59.47 cm, with the highest shoot length observed at 4MAP in 2021 and 2022. For the 50-55 mm diameter class, the shoot lengths ranged from 10.04 cm to 59.36 cm, with the highest shoot length observed at 4MAP in 2021 and 2022. In the 55-60 mm diameter class, the shoot lengths ranged from 9.89 cm to 59.27 cm, with the highest shoot length observed at 6 MAP in 2022. The highest shoot lengths were generally observed at 4 MAP in 2021 and 2022, regardless of the diameter class. The shoot lengths decreased as the diameter class increased, with the 55-60 mm diameter class having the lowest shoot lengths.

Table 3: Pooled Shoot Length (cm) in Different Diameter Class of Annual *Moringa* cuttings (*Moringa oleifera*)

Treatments	1MAP			2MAP			3MAP			4MAP			5MAP			6MAP		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
25-30 mm diameter	10.42	9.032	10.37	18.52	17.333	18.57	27.89	26.633	27.90	37.257	36.033	37.28	48.52	47.333	48.57	59.49	58.3	59.63
30-35 mm diameter	10.49	9.29	10.45	18.59	17.59	18.69	27.99	26.89	28.04	37.29	36.29	37.39	48.59	47.59	48.69	59.51	58.59	59.65
35-40 mm diameter	10.31	9.22	10.28	18.457	17.52	18.51	27.82	26.82	27.84	37.22	36.22	37.24	48.457	47.52	48.51	59.457	58.387	59.51
40-45 mm diameter	10.256	8.88	10.24	18.41	17.18	18.47	27.71	26.48	27.77	37.11	35.88	37.17	48.41	47.18	48.47	59.41	58.18	59.46
45-50 mm diameter	10.232	9.056	10.22	18.357	17.357	18.54	27.657	26.657	27.84	37.057	36.057	37.24	48.357	47.357	48.54	59.357	58.357	59.47
50-55 mm diameter	10.08	8.523	10.04	18.333	17.057	18.36	27.633	26.257	27.66	37.033	35.857	37.06	48.333	47.057	48.36	59.333	58.057	59.36
55-60 mm diameter	10.057	9.11	9.89	18.18	17.41	18.22	27.48	26.71	27.47	36.88	36.11	36.97	48.18	47.41	48.22	59.29	58.577	59.27
F-test	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
C.D.	0.614	0.956	0.243	0.185	0.971	0.126	0.179	0.910	0.258	0.168	0.902	0.687	0.182	0.921	0.489	0.201	0.913	0.654
SE(m)	0.269	0.373	0.071	0.200	0.298	0.087	0.180	0.329	0.076	0.187	0.269	0.090	0.200	0.298	0.087	0.212	0.296	0.092
SE(d)	0.381	0.527	0.101	0.283	0.422	0.123	0.255	0.466	0.107	0.264	0.381	0.127	0.283	0.422	0.124	0.299	0.418	0.130
C.V.	4.546	6.316	0.989	1.883	2.785	0.668	1.127	2.048	0.386	0.872	1.251	0.341	0.716	1.064	0.255	0.617	0.860	5.634

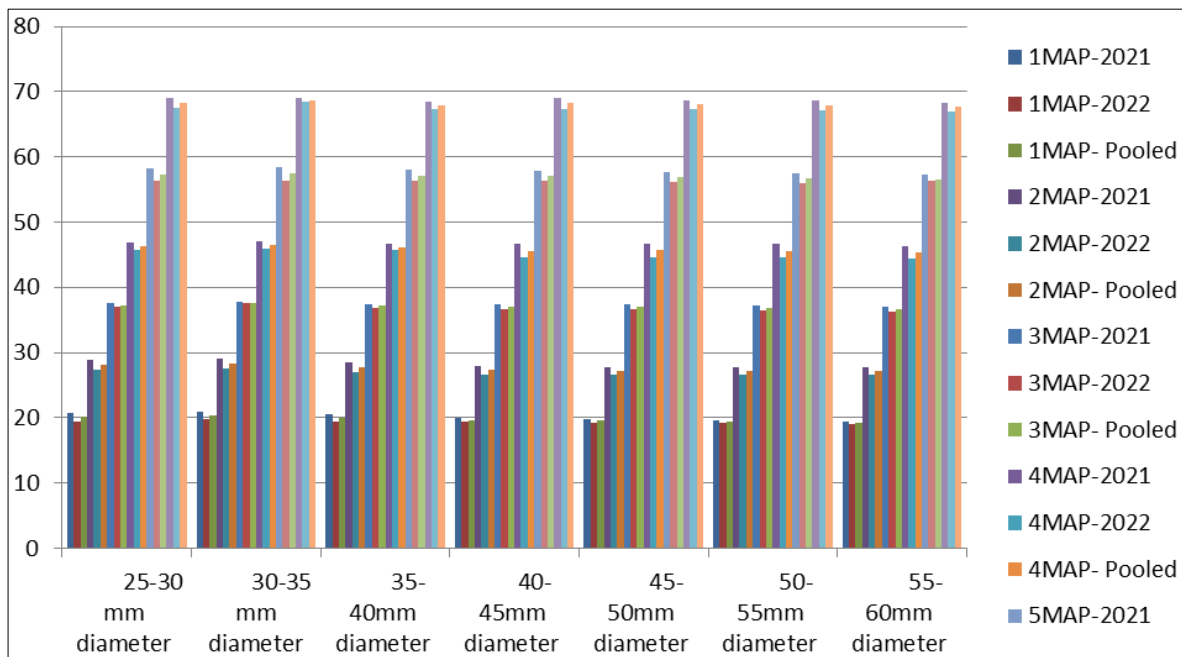


Fig 3: Shoot Length (cm) in Different Diameter Class of Annual *Moringa* cuttings (*Moringa oleifera*) Pooled

Plant Height (cm) in Different Diameter class of Annual *Moringa* cuttings (*Moringa oleifera*)

The plant heights (in cm) for different diameter classes of Annual *Moringa* cuttings (*Moringa oleifera*) at different time points shown in table 4 were as follows: In the 1st month after planting (1MAP), the highest plant height was observed in the 45-50 mm diameter class with a height of 19.7 cm, followed by the 50-55 mm diameter class with a height of 19.6 cm. The lowest plant height was recorded in the 55-60 mm diameter class with a height of 19.33 cm. In

the 6th month after planting (6 MAP), the highest plant height was recorded in the 45-50mm diameter class with a height of 45.654 cm, followed by the 50-55 mm diameter class with a height of 45.59 cm. The lowest plant height was observed in the 55-60 mm diameter class with a height of 45.335 cm. The plant heights generally increased as the diameter class decreased, with the highest heights observed in the 45-50 mm diameter class and the lowest heights in the 55-60 mm diameter class.

Table 4: Pooled Plant Height (cm) in Different Diameter class of Annual *Moringa* cuttings (*Moringa oleifera*)

Treatments	1MAP			2MAP			3MAP			4MAP			5MAP			6MAP		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
25-30 mm diameter	20.8	19.45	20.125	28.86	27.42	28.140	37.5	37	37.250	46.8	45.68	46.240	58.3	56.36	57.330	69	67.5	68.250
30-35 mm diameter	21	19.7	20.350	29.1	27.51	28.305	37.8	37.5	37.650	47	46	46.500	58.5	56.38	57.440	69.1	68.4	68.750
35-40 mm diameter	20.5	19.4	19.950	28.5	27	27.750	37.42	36.82	37.120	46.7	45.67	46.185	58	56.34	57.170	68.5	67.42	67.960
40-45 mm diameter	20	19.35	19.675	28	26.65	27.325	37.4	36.67	37.035	46.66	44.6	45.630	57.9	56.3	57.100	69	67.38	68.190
45-50 mm diameter	19.7	19.3	19.500	27.68	26.6	27.140	37.39	36.65	37.020	46.64	44.667	45.654	57.66	56.2	56.930	68.68	67.35	68.015
50-55 mm diameter	19.6	19.2	19.400	27.67	26.58	27.125	37.2	36.5	36.850	46.6	44.58	45.590	57.5	56	56.750	68.6	67.2	67.900
55-60 mm diameter	19.33	19	19.165	27.65	26.52	27.085	37	36.3	36.650	46.33	44.34	45.335	57.3	56.36	56.450	68.3	67	67.650
F-test	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
C.D.	1.246	0.938	1.12	1.864	0.909	1.652	1.648	0.915	0.938	1.589	0.945	2.246	1.641	0.931	2.489	1.942	0.961	1.842
SE (m)	0.309	0.418	0.446	0.218	0.766	0.663	0.218	0.356	0.314	0.282	0.309	0.834	0.218	0.454	0.863	0.218	0.504	0.653
SE (d)	0.436	0.591	0.631	0.309	1.084	0.938	0.309	0.504	0.444	0.398	0.436	1.180	0.309	0.642	1.220	0.309	0.713	0.924
C.V.	2.718	3.753	3.197	1.357	4.951	3.403	1.018	1.68	1.197	1.045	1.185	2.572	0.653	1.403	2.140	0.549	1.296	1.357

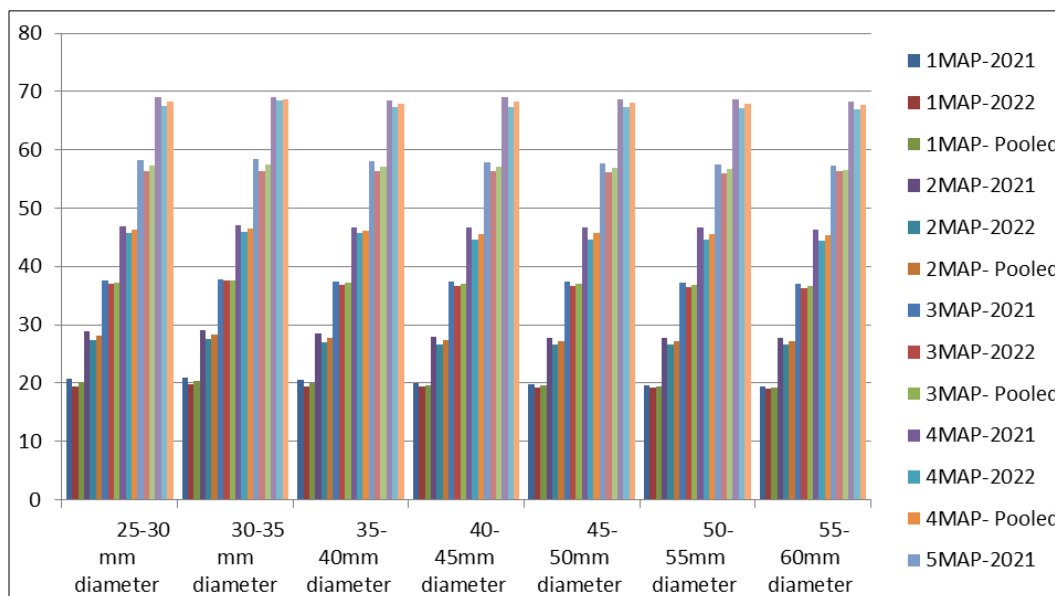


Fig 4: Plant Height (cm) in Different Diameter class of Annual *Moringa* cuttings (*Moringa oleifera*) Pooled

Leaf Area Index in Different Diameter class of Annual *Moringa* Cuttings (*Moringa oleifera*)

The Leaf Area Index (LAI) for different diameter classes of annual *Moringa* cuttings (*Moringa oleifera*), the pooled treatments for each year shown in table 5 are as follows for the 2021 and 2022 planting years, the highest LAI was observed in the 25-30 mm diameter class, with values of 3.863 and 2.57, respectively. The pooled LAI for this diameter class was 3.22. The second highest LAI was found in the 30-35 mm diameter class, with values of 3.79 and 2.58 for the 2021 and 2022 planting years, respectively. The

pooled LAI for this diameter class was 3.19. The 35-40 mm diameter class had the third highest LAI, with values of 3.767 and 2.56 for the 2021 and 2022 planting years, respectively. The pooled LAI for this diameter class was 3.16. The lowest LAI was observed in the 55-60 mm diameter class, with values of 3.643 and 2.32 for the 2021 and 2022 planting years, respectively. The pooled LAI for this diameter class was 2.98. The highest LAI was found in the 25-30 mm diameter class, followed by the 30-35 mm diameter class, and so on, with the lowest LAI in the 55-60 mm diameter class.

Table 5: Leaf Area Index in Different Diameter class of Annual *Moringa* Cuttings (*Moringa oleifera*) Pooled

Treatments	2MAS			4MAS			6MAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
25-30 mm diameter	3.863	2.57	3.22	8.987	7.66	8.32	14.933	13.53	14.23
30-35 mm diameter	3.79	2.58	3.19	8.91	7.69	8.30	14.9	13.63	14.27
35-40 mm diameter	3.767	2.56	3.16	8.77	7.65	8.21	14.867	13.5	14.18
40-45 mm diameter	3.733	2.55	3.14	8.767	7.49	8.13	14.833	13.47	14.15
45-50 mm diameter	3.723	2.46	3.09	8.753	7.47	8.11	14.8	13.43	14.12
50-55 mm diameter	3.667	2.32	2.99	8.72	7.46	8.09	14.75	13.4	14.08
55-60 mm diameter	3.643	2.32	2.98	8.71	7.42	8.07	14.733	13.27	14.00
F-test	S	S	S	S	S	S	S	S	S
C.D.	3.863	0.410	0.143	8.987	0.431	0.140	14.933	0.451	0.165
SE(m)	0.093	0.094	0.042	0.117	0.094	0.041	0.112	0.099	0.089
SE(d)	0.131	0.134	0.060	0.165	0.133	0.058	0.158	0.140	0.126
C.V.	4.365	4.375	1.607	2.31	1.853	0.663	1.323	1.159	0.853

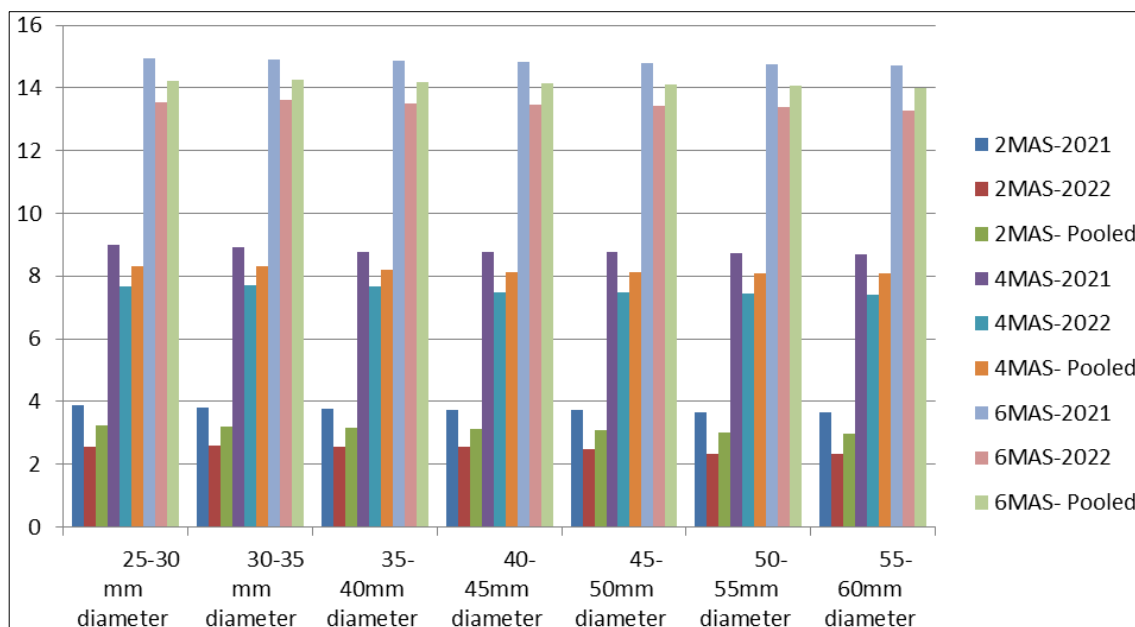


Fig 5: Leaf Area Index in Different Diameter class of Annual *Moringa* Cuttings (*Moringa oleifera*) Pooled

Conclusion

This research suggests that smaller diameter cuttings have a better chance of survival compared to larger ones. As the diameter increases beyond 35 mm, the survival percentages start to decline. The findings of this study suggest that the diameter of *Moringa* cuttings can influence their survival, growth, and leaf area index. Smaller diameter classes (25-30 mm and 30-35 mm) showed better performance in terms of survival, shoot length, plant height, and leaf area index. These results can guide farmers and researchers in selecting appropriate diameter classes for *Moringa* cuttings and implementing cultivation practices that maximize their growth and productivity. Further studies are recommended to explore the underlying factors contributing to these differences in performance among diameter classes.

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