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# EVALUATION OF *MORINGA OLEIFERA* VARIETIES FOR POD YIELD AND SPACING IN ARID WESTERN RAJASTHAN, INDIA

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**ABSTRACT**

Cultivation of moringa is restricted mainly to southern parts of India, even though it is a potential plant for arid and semi arid region, because of its adaptability, multipurpose and nutrient value which can aid in combat malnutrition, unemployment, deforestation, land degradation, fodder shortage and migration problem. To fully harness the benefits of the moringa plant, it is essential to evaluate different varieties and optimal spacing for higher yields in arid and semi-arid areas. The experiment was conducted at ARS Keshwana, Jalore, Rajasthan in a Factorial Randomized Block Design with three replication, eight varieties, five spacing and forty treatment combinations. Data on stem diameter (cm), height (m), number of branches/plants, pod/ plant, pod weight (kg/tree), yield (t/ha), income (lakhs/ha) and Benefit cost ratio was calculated. All data collected were pooled and subjected to two-way Analysis of Variance (ANOVA). As per the result obtained variety $V_4$(ODC 3) showed highest value for pod yield and B/C ratio fallowed by $V_1$ (PKM 1) and V6 (Bhagya) which was statistically superior to other varieties. S1 (3.0 m X 1.5 m) showed highest value for growth and yield parameters fallowed by S2 (2.5m X 2.5m). V4S1, V4S2 and V1S1 and V6S1 showed higher pod yield and B/C ratio. Varieties ODC 3 (V4), PKM 1(V1) and Bhagya (V6) performance was good under the spacing S1- 3m X 1.5m in arid Rajasthan condition and can be recommended for cultivation in arid Rajasthan for pod production.
***Keywords*:** *Moringa oleifera*, varieties, Spacing, Pod, Yield

## Introduction

*Moringa oleifera Lam* is otherwise known as the horseradish tree, drumstick tree, or oleoresin tree and is the most popular of its species one of the most recognized and widely utilized species of its kind. It has been speculated to have been brought from the locations of the Indian subcontinent, the Himalayan region, and some other parts of East Africa (Tamang & Tashi, 2020). A perennial tree, Moringa thrives in tropical and subtropical climates, thus reaching a height of 5 to 10 meters with trunks up to 25 cm thick (Samadia *et al*., 2019; Mashau *et al*., 2021). Moringa can be propagated from seeds or cuttings that germinate easily in all types of soil, though it is more successful if the pH level of the soil is neutral to slightly acidic. Yet, it is sensitive to frost or frost and its roots cavern in waterlogged surroundings easily. Water requirement of this species is very less, thus is a good plant to be used in dry regions and it can be grown with the help of rainwater (Amaglo *et al*., 2006; Samadia & Haldhar, 2018). Moringa, a powerhouse of nutrition and inexpensive, is primarily a food supplement made for both humans and animals. The plant is known for its richness in carotenoids, phenolics (such as chlorogenic acids), flavonoids (including quercetin and kaempferol glycosides), vitamins, and minerals. It is a source of all essential amino acids and has more β-carotene levels than carrots, vitamin C careen than oranges, potassium than bananas, and calcium than milk, besides being one of the best sources of iron as well (Foid *et al*., 2001; Becker & Siddhuraju, 2003; Bennett *et al*., 2003; Samadia & Haldhar, 2017; Gopalakrishnan *et al*., 2016).

India is the world's leading producer of moringa, with an annual yield of 1.1 to 1.3 million tonnes of fruit harvested across 380 km². Andhra Pradesh has the largest cultivation area at 156.65 km², followed by Karnataka (102.8 km²) and Tamil Nadu (74.08 km²). Moringa is commonly cultivated in home gardens and as living fences in Odisha and southern India, and it is also marketed locally in Thailand (Pradhan *et al.*, 2023 and Saresh *et al.*, 2024). Despite its adaptability, multipurpose uses, and high nutrient value, the cultivation of moringa is mainly concentrated in southern India. This is due to its potential to combat issues such as malnutrition, unemployment, deforestation, land degradation, fodder shortages, and migration, all of which impact nutritional and livelihood security.

To fully capitalize on the benefits of moringa, it is crucial to assess different varieties and spacing techniques to optimize yields, particularly in arid and semi-arid regions. In areas where large-scale cultivation is practiced, moringa often receives little attention as it is primarily grown as an agroforestry or boundary tree. Expanding cultivation to meet increasing demand can be challenging and environmentally damaging (Okigbo, 1984). Therefore, it is essential for farmers to adopt the right cultivation strategies to achieve reliable and sufficient yields while preserving natural resources. This study aims to evaluate the productivity of *Moringa oleifera* as a vegetable in India's arid regions, with a focus on determining the optimal spacing for sustainable pod production.

## Material and Methods

### Study site

The experiment was conducted at Agricultural Research Station, Keshwana, Jalore, Rajasthan. The site is located at latitude $25^{0}23^{|}14.22^{||}$N and longitude of $73^{0}30^{|}43.08^{||}$E, elevation 149.9 msl. Jalore comes under the lower transect in arid western Rajasthan (Fig. 1).

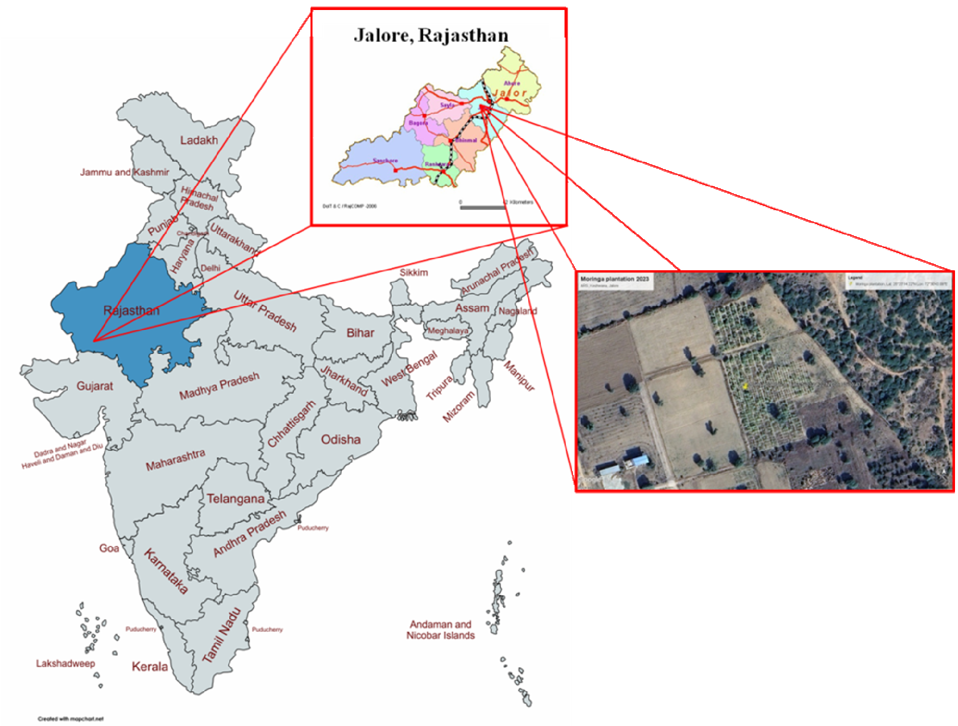


**Fig. 1 :** View of study site

### Treatments

The experiment was laid in a Factorial Rrandomized Block Design which consists of eight varieties (locally available perennial moringa as control because no annual recommended varieties of moringa are available in the Package of Practice of Zone IIb (Transitional plains of *Luni* basin) of Rajasthan and five spacing and its combination with three replication (Table 2). Plantation management was done as per the requirement. The plantation was established during September 2022 and data were collected for two years.

**Table 2 :** Treatment and its combination

| Varieties (V) | Spacing (S) | Treatment combination (V×S) | | | | |
|---|---|---|---|---|---|---|
| $V_1$ – PKM 1 | $S_1$: 3.0 m x 1.5 m | $V_1S_1$ | $V_1S_2$ | $V_1S_3$ | $V_1S_4$ | $V_1S_5$ |
| $V_2$ – PKM 2 | $S_2$: 2.5 m x 2.5 m | $V_2S_1$ | $V_2S_2$ | $V_2S_3$ | $V_2S_4$ | $V_2S_5$ |
| $V_3$ – ODC | $S_3$: 1.5 m x 1.0 m | $V_3S_1$ | $V_3S_2$ | $V_3S_3$ | $V_3S_4$ | $V_3S_5$ |
| $V_4$ – ODC-3 | $S_4$: 1.2 m x 1.2 m | $V_4S_1$ | $V_4S_2$ | $V_4S_3$ | $V_4S_4$ | $V_4S_5$ |
| $V_5$ – Rohit-1 | $S_5$: 1.0 m x 1.0 m | $V_5S_1$ | $V_5S_2$ | $V_5S_3$ | $V_5S_4$ | $V_5S_5$ |
| $V_6$ – Bhagya | | $V_6S_1$ | $V_6S_2$ | $V_6S_3$ | $V_6S_4$ | $V_6S_5$ |
| $V_7$ – GKVK 2 | | $V_7S_1$ | $V_7S_2$ | $V_7S_3$ | $V_7S_4$ | $V_7S_5$ |
| $V_8$ – Local | | $V_8S_1$ | $V_8S_2$ | $V_8S_3$ | $V_8S_4$ | $V_8S_5$ |

**Soil characters**

The experimental site's soil has been classified as sandy loam. According to Table 1, the surface soil is loamy in texture. The pH is 8.1, indicating a slightly alkaline nature, with an electrical conductivity (EC) of 0.67. The soil has a low organic carbon content of 0.52%. Nitrogen availability is also low at 156.3 kg $ha^{-1}$, while phosphorus is at a medium level (11.4 kg $ha^{-1}$), and potassium availability is low at 30.29 kg $ha^{-1}$.

**Table 1 :** Soil physico-chemical characteristics of the study site.

| Parameters | Value |
|---|---|
| pH | 8.1 |
| EC (mS/cm) | 0.67 |
| OC (%) | 0.52 |
| Available Nitrogen (kg $ha^{-1}$) | 156.3 |
| Phosphorus (kg $ha^{-1}$) | 11.4 |
| Potassium (kg $ha^{-1}$) | 30.29 |

**Data collection and analysis**

Data on stem diameter (cm) was measured at the bottom part using caliper at major and minor axis then its average value was recorded. The height (m) of the plant was determined by measuring the distance from the soil surface to the tip of the fully opened leaf on the main shoot by measuring tape. Number of branches/plants, pod/ plant counted manually, pod weight per tree (kg/tree) were measured with a balance, yield (t/ha), income (lakhs/ha) and Benefit cost ratio (Singh *et al.,* 2017) was calculated for 2022 to 2024. All data collected were pooled and subjected to two-way Analysis of Variance (ANOVA).

## Result and Discussion

The results and literature related to evaluation of moringa varieties with respect to spacing and pod production is substantiated in this chapter. Since the literature related to the interaction effect among varieties and spacing effect on pod yield is meager, reviews related to these factors in other crops is also included.

**Growth parameter**

**Diameter (cm), height (m) and number of branches**

The highest recorded stem diameter was observed in $V_1$ (30.02 cm), followed by $V_4$ (15.67 cm) and $V_2$ (15.45 cm), with $V_8$ having the smallest diameter (8.44 cm). Regarding plant height, $V_1$ was the tallest (1.92 m), followed by $V_2$ (1.86 m) and $V_4$ (1.78 m), while $V_8$ had the shortest height (1.51 m). For spacing, the largest diameter was recorded in $S_4$ (16.77 cm), followed by $S_3$ (15.79 cm) and $S_2$ (14.17 cm). In terms of height, $S_1$ produced the tallest plants (1.76 m), followed by $S_4$ (1.74 m) and $S_2$ (1.69 m) (Table 1). When considering interaction effects, the highest stem diameter was observed in $V_1S_4$ (40.12 cm), followed by $V_1S_3$ (39.61 cm) and $V_1S_2$ (31.07 cm). Lower diameters were recorded in $V_4$ combinations, with values of 18.33 cm ($V_4S_4$), 17.22 cm ($V_4S_3$), and 15.14 cm ($V_4S_2$) (Fig 2a). For height, the interaction combination was $V_3S_1$ (2.24 m), followed by $V_3S_2$ (2.17 m), $V_1S_2$ (2.12 m), and $V_4S_4$ (2.11 m) (Fig 2b). In terms of branching, the highest number of branches was observed in varieties $V_4$ (87.93), $V_2$ (87.67), and $V_7$ (67.47). For spacing, the highest branch counts were recorded in $S_1$ (75.33), $S_4$ (72.29), and $S_3$ (68.59). Among interaction combinations, $V_4S_1$ (102), $V_2S_1$ (100), and $V_4S_4$ (97) performed the best. Sakdeo (2019) reported that PKM-1 moringa variety exhibited the greatest plant height compared to other verities. Similarly, Selvakumari and Ponnuswami (2013) also observed that tree height ranged from 3.2 to 7.8 m under Periyakulam conditions. Rajamanickam and Arokiamary (2022) revealed that PKM-1 variety recorded the highest values for height followed by other varities. As per Pradhan *et al*. (2023) the wider spacing produced a more significant number of branches and higher yield per plant compared to the medium and close spacing, the total shoot yield per hectare was higher in the close spacing than in the medium and wide spacing. According to the study, the growth and yield of Moringa were significantly influenced by spacing, with leaf production, branches, and overall yield being particularly affected. Amaglo (2006) observes that increasing plant density promotes accelerated growth, which may explain the increased heights pragmatic with closer spacing. However, plant growth is shaped by a complex interaction of external and internal factors within an organized system. As suggested by Janick (1972) and Norman (1992) plant population density rises, competition intensifies for vital resources such as nutrients, sunlight, and water. This keen competition can reduce the availability of these critical factors, ultimately impacting growth negatively. In another finding *Moringa stenopetala* it is proved to have a good growth performance at medium plant spacing and could provide nutritional needs for human as well as livestock in semi-arid region of Nigeria (Abdullahi and Maishanu, 2021). The annual moringa varieties (PKM 1 and Bhagya (KDM-1)) recorded 60 per cent increased yield over the local variety (Rajamanickam 2019, Rajamanickam and Arokiamary 2022). In an experiment conducted on groundnut, growth and yield was significantly influenced by the plant spacing. Yenyawoso variety with wider plant spacing performed better vegetatively and produced the highest number of pods among all the varieties (Iddrisu *et al*., 2024).

**Pod yield and Benefit cost ratio**

The highest number of pods per tree was recorded in $V_4$ (107.99), followed by $V_6$ (104.00) and $V_1$ (103.67). Among spacing treatments, $S_1$ produced the most pods per tree (130.46), followed by $S_2$ (110.67) and $S_3$ (73.87), with the lowest number observed in $S_5$ (73.87) (Table 2). In terms of specific combinations, the highest pod production per plant was found in $V_6S_1$ (162), $V_4S_1$ (161), $V_1S_1$ (159), and $V_1S_2$ (158) (Fig 2c). Pod yield per tree was greatest in $V_4$ (5.16 kg), followed by $V_6$ (4.94 kg) and $V_1$ (4.67 kg), with $V_8$ having the lowest yield. For spacing, $S_1$ achieved the highest yield (7.21 kg), followed by $S_2$ (6.94 kg) and $S_3$ (2.28 kg) (Table 2). Regarding interaction effects, the highest pod yields per tree were observed in $V_4S_1$ (9.57 kg), $V_4S_2$ (9.53 kg), and $V_7S_2$ (9.18 kg), followed by $V_7S_1$ (8.84 kg), $V_1S_1$ (8.71 kg), and $V_1S_2$ (8.58 kg) (Fig 2d). Pod yield per hectare was highest in $V_4$ (19.04 t/ha), followed by $V_1$ (18.43 t/ha) and $V_6$ (17.78 t/ha). Among spacing treatments, $S_1$ consistently produced the highest yield across all varieties (16.35 t/ha), followed by $S_2$ (16.02 t/ha) and $S_3$ (15.85 t/ha) (Table 2). The most productive interaction combinations were $V_4S_1$ (21.27 t/ha), $V_1S_1$ (19.91 t/ha), and $V_7S_1$ (19.63 t/ha), which outperformed other combinations (Fig 2e). The Benefit-Cost Ratio (BCR) was highest for $V_4$ (2.14), followed by $V_1$ (2.07) and $V_6$ (1.99). Among spacing, $S_1$ had the highest BCR (1.89), followed by $S_2$ (1.77) and $S_3$ (1.72) (Table 2). For interaction effects, $V_4S_1$ achieved the highest BC ratio (2.51), followed by $V_1S_1$ and $V_6S_1$, both with a BC ratio of 2.35 (Fig 2f). Rajamanickam and Arokiamary (2022), Malathi *et al.* (2021) and Karinakar *et al.* (2018), reported that annual moringa varieties i.e. PKM 1 and Bhagya (KDM 1) exhibited highest pod yield and registered almost doubling in the net profit of moringa farmers of Salem, Tamil Nadu. Norman (1992) and Foid (2001) also explained that increasing plant density does not impact individual plants as long as the density remains below the threshold where competition begins. However, when plant density exceeds this threshold, competition among plants reduces overall yield. Each crop has a defined marketable size and quality, and while high plant densities may induce competition, they can still be utilized if the harvested crop meets marketable standards. As planting density rises, yield per plant decreases due to increased total biomass production per unit area. Despite this, the higher plant population can offset the reduced yield per plant, maintaining overall productivity. According to several researchers, wider-spacing provides greater yields than systems with closer spacing (Mickelson and Renner (1997) and Munir *et al*., 2011), which may be related to efficient use more water, nutrients, and probably most crucially, light (Iddrisu *et al*., 2024). Sakdeo (2019) reported that moringa varietal plot gained highest cost benefit ratio (1:3.5) then the farmers' practices with lowest cost benefit ratio (1:2.7).

**Table 2 :** Effect of varieties and spacing on growth and yield of *Moringa oleifera*

| Treatments / Varieties | | Diameter (cm) | Height (m) | No. of Branches | No of Pods/tree | Pod yield/tree (Kg/tree) | Yield/ha (t/ha) | Income /ha (Rs in lakhs) | B:C |
|---|---|---|---|---|---|---|---|---|---|
| **V1** | | 30.02 | 1.92 | 67.07 | 103.67 | 4.67 | 18.43 | 4.61 | 2.07 |
| **V2** | | 15.45 | 1.86 | 87.67 | 103.60 | 3.76 | 15.59 | 3.90 | 1.74 |
| **V3** | | 12.72 | 1.70 | 66.33 | 99.00 | 4.44 | 16.52 | 4.13 | 1.85 |
| **V4** | | 15.67 | 1.78 | 87.93 | 107.99 | 5.16 | 19.04 | 4.76 | 2.14 |
| **V5** | | 10.09 | 1.56 | 60.27 | 99.40 | 3.81 | 15.49 | 3.87 | 1.73 |
| **V6** | | 11.41 | 1.62 | 62.80 | 104.00 | 4.94 | 17.78 | 4.44 | 1.99 |
| **V7** | | 11.28 | 1.69 | 67.47 | 98.60 | 4.66 | 17.12 | 4.28 | 1.92 |
| **V8** | | 8.44 | 1.51 | 45.80 | 0.00 | 0.00 | 0.07 | 0.007 | 0.003 |
| **Spacing** | | | | | | | | | |
| **S1** | | 11.87 | 1.76 | 75.33 | 130.46 | 7.21 | 16.35 | 4.08 | 1.89 |
| **S2** | | 14.17 | 1.69 | 66.46 | 110.67 | 6.94 | 16.02 | 4.00 | 1.77 |
| **S3** | | 15.79 | 1.68 | 68.58 | 73.87 | 2.28 | 15.85 | 3.96 | 1.72 |
| **S4** | | 16.77 | 1.74 | 72.29 | 67.25 | 1.63 | 11.10 | 2.78 | 1.31 |
| **S5** | | 13.38 | 1.66 | 58.17 | 65.42 | 1.57 | 15.71 | 3.93 | 1.71 |
| **V** | **SEm±** | 0.05 | 0.07 | 3.70 | 1.10 | 0.07 | 0.36 | | |
| | **CD (5%)** | 0.14 | 0.20 | 10.43 | 3.10 | 0.21 | 1.03 | | |
| | **CV** | 2.11 | 12.02 | 4.88 | 2.46 | 2.36 | 2.43 | | |
| **S** | **SEm±** | 0.04 | 0.05 | 2.92 | 0.87 | 0.05 | 0.29 | | |
| | **CD (5%)** | 0.11 | NS | 8.25 | 2.45 | 0.16 | 0.81 | | |
| | **CV** | 7.45 | 19.14 | 10.41 | 3.05 | 1.35 | 6.83 | | |


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## Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## Competing Interests

Authors have declared that no competing interests exist.

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