



Effect of spacing and harvest duration of moringa leaves in Arid Region

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Summary

Moringa oleifera Lam, a member of the Moringaceae family, is highly prized and grows in many tropical and subtropical countries. It has a broad spectrum of medicinal uses and is highly nutritious. An experiment was conducted to investigate how spacing and harvest duration impact the growth, leaf yield, and quality of *Moringa oleifera* Lam at the College of Agriculture, Jodhpur, Rajasthan. The study involved spacing treatments of 60 x 60 cm, 60 x 45 cm, and 45 x 45 cm as well as harvest durations of 30, 45, and 60 days. Randomly selected individual plants from each harvest plot were analyzed to record the fresh leaves and air-dried weights. Additionally, the plant's average stem diameter, height, and branches were recorded. According to the results, over a 60-day period after sowing, there was a steady increase in plant height. The 60 x 60 cm, 60 x 45 cm, and 45 x 45 cm spacings resulted in plant heights of 92 cm, 96 cm, and 102 cm, respectively. The number of branches produced per plant also increased with time, reaching 10 and 12 for medium and wide spacings, respectively. Although the wider spacing produced a more significant number of branches and higher yield per plant compared to the medium and close spacings, the total shoot yield per hectare was higher in the close spacing than in the medium and wide spacings. 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.

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Introduction

The Moringaceae family consists of approximately 13 species of moringa trees, including *M. arborea*, *M. drouhardi*, *M. borziana*, *M. hildebrandtii*, *M. longituba*, *M. oleifera*, *M. ovalifolia*, *M. peregrina*, *M. concanensis*, *M. ruspoliana*, *M. stenopetala*, *M. pygmaea*, and *M. rivae*. The *Moringa oleifera* Lam tree, also known as horseradish, drumstick, and ben oil tree, is the most well-known and widely used among them, and is believed to have originated from India, the Himalayan region, and some areas around the Red Sea (Tamang & Tashi 2020). The tree is a perennial crop that thrives in tropical and subtropical regions, and can grow to heights of 5 to 10 m with trunks up to 25 cm thick (Samadia et al. 2019; Mashau et al. 2021). It can be cultivated from either seed or cuttings and prefers neutral to slightly acidic soil, but can tolerate a wide range of soil conditions. Moringa cannot tolerate freezing or frost conditions and roots may rot in waterlogged areas. It only requires small amounts of water and can be grown using rainwater, making it particularly suitable for dry regions (Amaglo et al. 2006; Samadia & Haldhar 2018). Commercial varieties of Moringa, such as KM 1, PKM 1, PKM 2, GKVK 1, GKVK 2, GKVK 3, Dhanaraj, Bhagya (KDM 01), Konkan Ruchira,

and Rohit, are available based on soil and climatic conditions (Masih et al. 2019).

India is a leading producer of moringa, annually yielding 1.1 to 1.3 million tonnes of fruits over an area of 380 km². Andhra Pradesh is the largest producer and has the largest area under cultivation, with 156.65 km², followed by Karnataka with 102.8 km² and Tamil Nadu with 74.08 km². Moringa is grown in home gardens and as living fences in Odisha and southern India and is locally marketed in Thailand. Moringa is a high-quality, low-cost food for humans and animals, with studies indicating that it contains carotenoids, phenolics (chlorogenic acids), flavonoids (quercetin and kaempferol glycosides), vitamins, and minerals (Foid et al. 2001; Becker & Siddhuraju 2003; Bennett et al. 2003; Samadia & Haldhar 2017). The leaf, in particular, is rich in protein, vitamins, and minerals, containing all the essential amino acids, higher β -carotene levels than carrots, more vitamin C than oranges, more potassium than bananas, and more calcium than milk, as well as being a good source of iron (Gopalakrishnan et al. 2016). Additionally, the leaf contains polyphenols and tannins that exhibit various biological activities, such as antiviral, antioxidant, and anticancer effects. It also prevents cardiovascular and liver disease, skin and digestive disorders, inflammations, and more than 300 other illnesses. In Senegal and Haiti, *M. oleifera* leaves powder has been used to treat malnutrition in small children, pregnant, and nursing women, as the leaves are an excellent source of vitamins and minerals (Prince 2000;

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Samadia & Haldhar 2019).

In order to fully utilize the benefits of the moringa plant, it is important to employ proper techniques, especially during the harvesting and post-harvesting stages. This article will specifically focus on the frequency and duration of leaf harvesting. In regions where large-scale cultivation of the plant is practiced, it often does not receive the necessary attention because it is primarily grown as an agro-forestry or boundary tree. Increasing production to meet the growing demand of the crop by expanding the cultivation area can be costly, challenging, and detrimental to the environment (Okigbo 1984). Therefore, it is crucial for growers to adopt appropriate strategies and techniques to achieve reliable and sufficient yields without compromising natural resources. To this end, it is necessary to establish the best agricultural practices for cultivation and utilization of the plant. This study was conducted to assess the productivity of *Moringa oleifera* as a leafy vegetable in the arid regions of India. The study aimed to determine the optimal spacing required for growing *Moringa oleifera* as a leafy vegetable, the effects of spacing on yield, and the appropriate harvest frequency necessary to maintain *Moringa oleifera* fields for continuous leaf production.

Materials and Methods

Experimental Site

The College of Agriculture at Agriculture University Jodhpur, Rajasthan (Latitude 26.35915, Longitude 73.04722) conducted experiments on July 27th, 2022 in an arid region of India. The area typically receives an annual rainfall of 362 mm from July to September, with a dry season from March to June. Throughout the year, temperatures range from 4°C to 48°C. During the period of the experiment, the relative humidity ranged from approximately 65% in the early mornings to 25% at noon.

Plantation and Land Preparation

The College of Agriculture at Agriculture University Jodhpur, Rajasthan housed the experimental plot of red rock, and moderately drained sandy soil. The study utilized a total land area of 30 x 18 meters divided into three blocks. The field was ploughed, harrowed, and levelled to a cloddy until the implementation of nine (9) treatments randomly distributed among the three blocks. The size of each plot was 1.8 x 30 meters square, separated by a 0.6-meter walkway. Throughout the study, the plots were well-maintained by removing weeds, watering as needed, and applying compost every two months of growth at a rate of 1.5 tons per hectare to prevent declining yields.

Crop Measurement Parameters

After transplanting 15-day-old seedlings, the cultivated *Moringa* seedlings were allowed to grow for an additional 15 days while their growth and development were monitored. Parameters such as plant height, number of branches, and stem girth were studied on a weekly basis for 60 days before harvesting. This 60-day duration was necessary to allow the rooting system to develop sufficiently to withstand the initial cut/harvest at the height of 25 cm above ground level. After the initial 60 days from sowing, subsequent harvests were performed

at 30-, 45-, and then 60-day intervals, respectively, based on the assigned treatments for each plot. The shoots were manually harvested by cutting with a knife at a height of 25 cm above ground level, and only the inner rows of each plot were cut and bulked for yield determinations. The fresh weight of the harvested shoots per plot was determined using a weighing scale in the field. Randomly selected plants were taken from each plot after harvesting, and their fresh weight were measured using an electronic beam balance in the laboratory. The leaves and twigs were placed into labelled brown paper envelopes and dried in an electric oven at 60°C for 72 hours. The dry weight of each sample was then recorded using an electric beam balance.

Results and Discussion

The impact of spacing on vegetative growth was examined during the first 60 days. The findings revealed that the seedlings displayed consistent growth 10-15 days following planting. The mean plant height increased over time evident from the 5th week onwards. The closest spacing (45 x 45 cm) resulted in the greatest increase in plant height, followed by the medium spacing (60 x 45 cm), and the widest spacing (60 x 60 cm) produced the smallest increase (refer to Figure 1). The average number of branches produced per plant over time is shown in Figure 2. There was an overall increase in the number of branches produced per plant over time in all treatments, except for the closest spacing which displayed a sharp decline from the 6th to 8th week. The widest spacing produced more branches per plant from plants in the medium and closest spacing treatments throughout the study period. Stem diameter increased over time in all treatments from planting seedlings. Individual plants with wider spacing had a larger girth, followed by those with medium spacing and closer spacing (Figure 3).

The observed trends in growth and development indicated significant increases in both plant height and number of branches across all treatments. The treatment with closer spacing resulted in the highest increases in plant height, whereas wider spacing showed relatively lower increases. Conversely, the number of branches per plant exhibited the opposite trend. Amaglo (2006) suggests that increasing plant density leads to accelerated plant growth and explains the increased heights in closer spacing. However, growth is influenced by a complex interplay of external and internal factors within an ordered system. As plant population density increases, competition for essential growth factors like nutrients, sunlight, and water arises, which can lead to a decrease in the concentration of these factors. Janick (1972) and Norman (1992) both suggest that this competition adversely affects plant growth. The performance of individual plants is only affected by an increase in plant density once the density reaches a level where competition occurs. At a spacing of 45 x 45 cm, competition for essential growth factors was so intense that the lower leaves of plants in this treatment died off, while the lower leaves in the 60 x 45 cm and 60 x 60 cm spacing treatments were healthy due to receiving sufficient growth factors. This suggests that competition

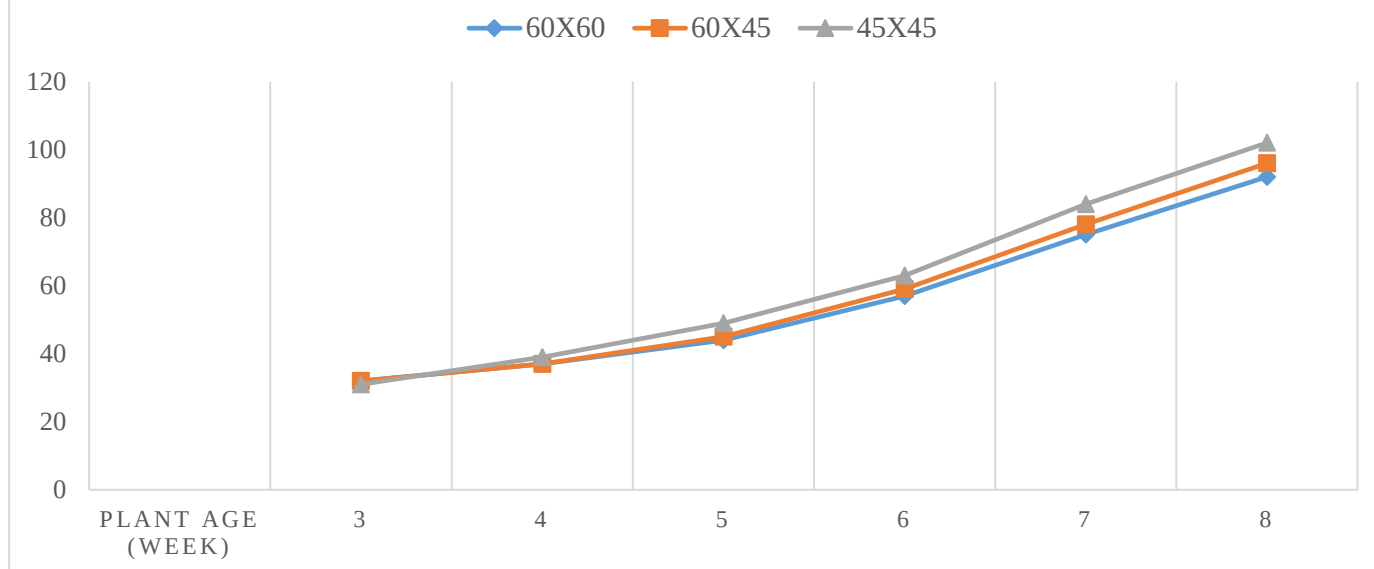
between plants occurs when plant density exceeds a threshold level.

Effect of Spacing on yield in 1st harvesting (60 Days)

At the first cut 60 days after sowing, there was no significant difference in the fresh and dry yield per plot. However, the data revealed that the widest spacing resulted in the highest fresh and dry shoot yield per plant, followed by the medium and closer spacing, respectively

(as depicted in Figure 4). Regarding yield per hectare, the closest spacing resulted in the highest yields of 14.67 quintals and 4.44 fresh and dry weight respectively. The medium spacing yielded 11.33 quintals of fresh weight and 15.73 quintals of dry weight per hectare. Conversely, the widest spacing had the most minuscule yield per hectare, with 9.33 quintals and 2.85 quintals of fresh and dry weight yield, respectively.

Fig. 1 Effect of age and spacing on plant height (cm)



Nonetheless, while similar, the trends in total fresh shoot yield per hectare exhibited significant differences. According to reports by Norman (1992) and Foid (2001), increasing plant density does not affect individual plants as long as the density is below the threshold level where competition arises. However, yield decreases when plant density exceeds this level and competition between plants occurs. Each crop has an acceptable marketable size and quality, and even though competition may exist

at high plant densities, such spacings may still be used, provided the harvested crop falls within the marketable size range. As planting density increases, yield per plant decreases due to higher total biomass production per unit area. Nevertheless, the higher number of plants per unit area can compensate for the lower production per plant.

Fig. 2 Effect of age and spacing on number of branches

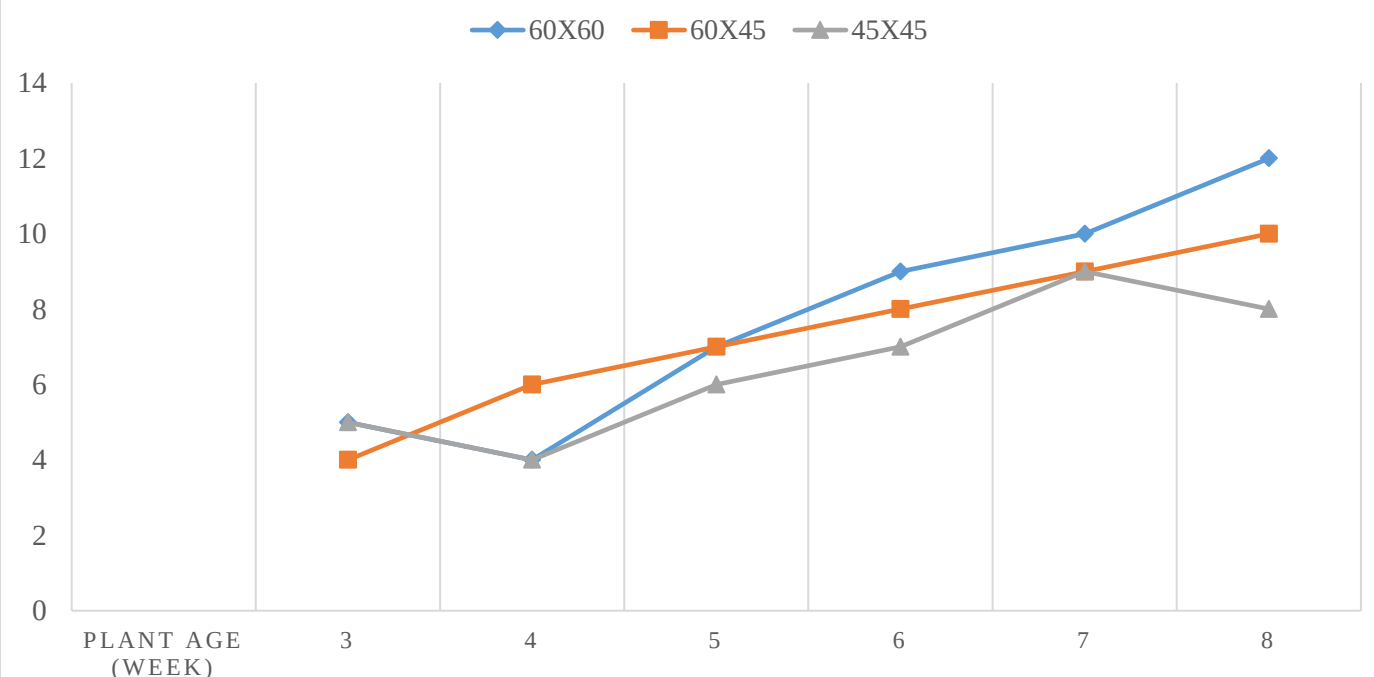
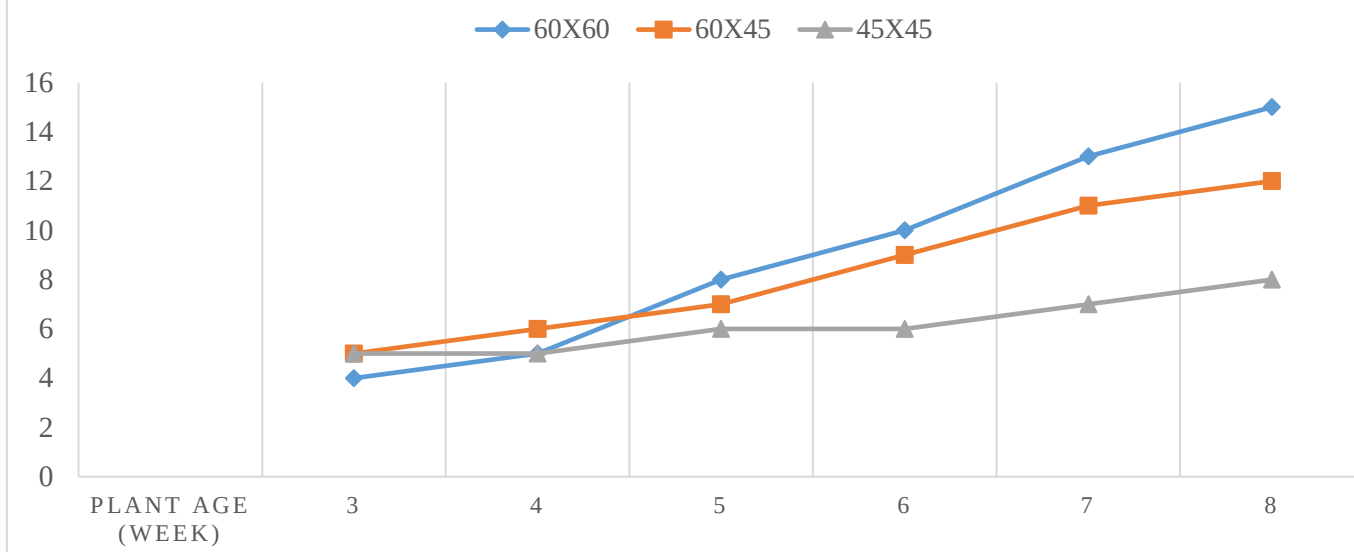
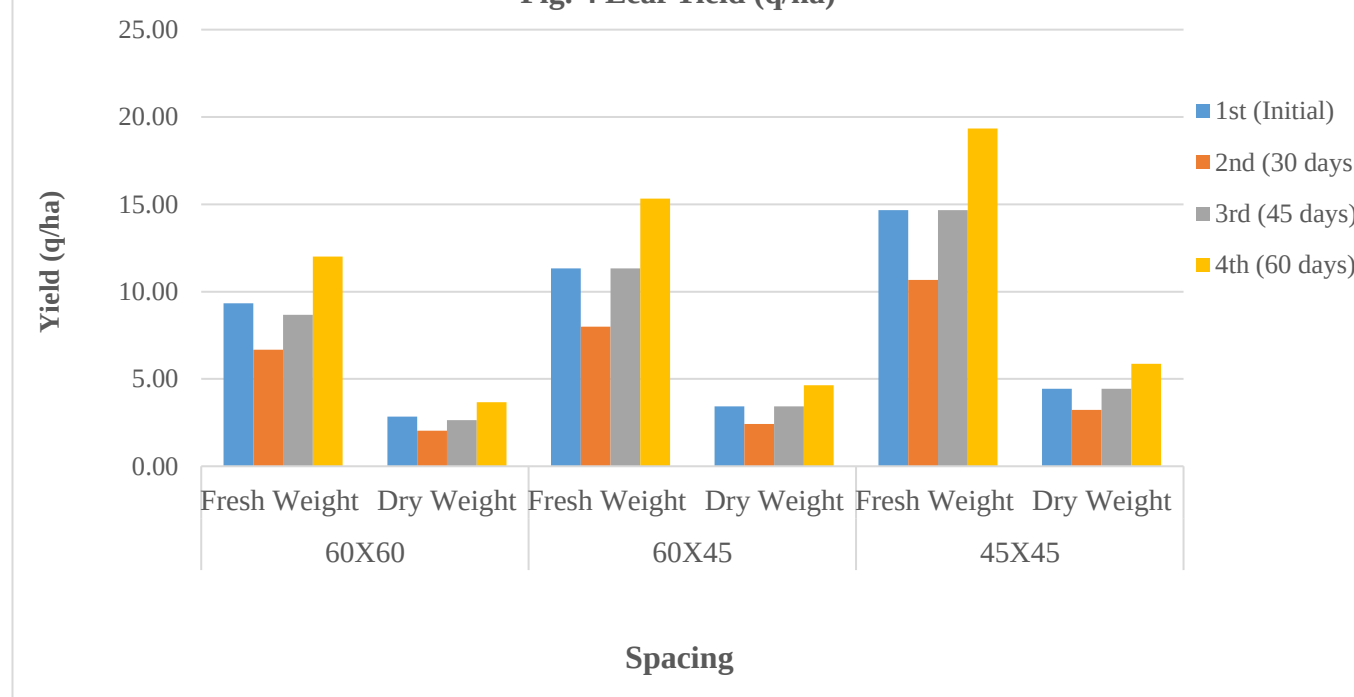


Fig. 3 Effect of spacing on stem diameter (mm)**Effect of Spacing and Number of Harvests on Yield**

Following the first harvest, which occurred 60 days after sowing, there were three additional harvests. Yield per plot generally increased at each successive harvest interval (30, 45, and 60 days, respectively), with a sharp increase observed during the last harvest. Applying compost resulted in an initial increase in subsequent yields. The spacing and frequency of harvest treatments did not significantly affect yield per plot, with the 60-day frequency treatment giving the highest yield per plot, followed by the 45-day harvest and the 30-day harvest giving the lowest. A sharp decline in yield was observed during the second harvest, followed by a rise in subsequent harvests. While there was a significant difference in yield per hectare due to spacing, the effect of harvest duration was not as pronounced. The closest spacing (45 x 45cm) gave the highest leaf yield per

hectare, followed by the medium spacing (60 x 45cm), with the widest spacing giving the lowest yield per hectare. This trend was observed for all four harvests.

Following harvest, a general fertilization with compost resulted in a slight increase in yield. This suggests that there is high competition for nutrients and other growth factors, and continuous nutrient intake by plants can result in depletion and a corresponding decline in leaf yield. Therefore, high productivity may only be maintained by continuously replenishing the nutrient intake by plants through a good fertilizer application program, preferably using organic fertilizers to avoid negative environmental and health impacts such as nitrate accumulation in water and the plant. As Moringa continues to grow between cuttings, the number of plants per hectare is significantly reduced due to differences in growth rates among the plants.

Fig. 4 Leaf Yield (q/ha)

Conclusion

The study's findings indicated that the spacing of Moringa plants had a considerable impact on their growth and yield, particularly with regards to leaf production, stem size, and overall yield. Therefore, when producing Moringa as a source of leafy vegetables, spacing during cultivation should be carefully considered alongside other factors affecting efficiency, such as plant loss after successive cuttings. Subsequent harvests should be conducted every 30 days following the initial harvest at 60 days after sowing, and additional fertilization is necessary to maintain high yields and plant survival over time.

Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

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