

Optimization of Rhizome Size and Planting Geometry for Improving Productivity and Profitability in Turmeric

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Abstract: Turmeric remains one of India's most important spice crops, valued for its culinary uses, medicinal compounds, and export potential. Despite its significance, farmers still rely on traditional planting material and planting geometry, often without understanding how these decisions affect growth, yield, and profitability. The present study examines the impact of varying rhizome sizes and planting geometries on vegetative development, yield components, curcumin content, and economic returns in turmeric under field conditions. Three seed-rhizome sizes (15–20 g, 30–35 g, and 45–50 g) and three planting geometries (30 × 30 cm, 45 × 30 cm, and 60 × 30 cm) were evaluated in a randomized block design with three replications. Growth parameters such as sprouting percentage, plant height, tiller count, and leaf area index were recorded periodically. Yield attributes including total fresh rhizome weight, mother and finger rhizome proportions, dry matter recovery, and curcumin content were measured at harvest. An economic analysis was conducted to understand net income and benefit–cost ratio across treatments. The results showed that large rhizomes achieved higher initial vigor and produced heavier clumps, but medium-sized rhizomes offered the most balanced performance and highest profitability due to lower planting material cost. Moderate spacing at 45 × 30 cm consistently produced optimal plant growth and maximum yield per hectare. The combined effect of medium rhizome size and 45 × 30 cm spacing resulted in the highest economic return. The study concludes that optimizing rhizome size and planting geometry is necessary for enhancing turmeric productivity while ensuring financial sustainability for farmers.

Keywords: Turmeric, Rhizome Size, Planting Geometry, Curcumin, Growth Response, Yield Components, Economics, Field Evaluation.

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I. INTRODUCTION

Turmeric has been cultivated for centuries as both a household spice and a medicinal plant. Its principal bioactive compound, curcumin, gives turmeric its characteristic color and therapeutic value. Over the last two decades, rising global demand has encouraged farmers to increase production, yet yield levels remain inconsistent across regions. This variability often stems from differences in planting material quality, soil fertility, local management practices, and climate conditions. Among these factors, seed-rhizome size and planting geometry are critical but frequently overlooked. Farmers traditionally select rhizomes based on availability rather than suitability. Seed pieces that are too small often lack stored reserves necessary for vigorous early growth, while excessively large rhizomes increase input costs without proportionate gains in yield. Achieving the right balance is essential to avoid unnecessary expenditure and ensure uniform crop establishment.

Plant spacing plays an equally important role. Dense spacing increases plant population but also intensifies competition for nutrients, water, and sunlight. Wider spacing improves individual plant growth yet may reduce the number of productive plants per unit area. What this really means is that growth and yield are shaped by the interaction between rhizome size and planting geometry. Understanding this interaction is crucial for developing recommendations that enhance productivity without increasing cultivation costs. This study was designed to address that gap. By systematically evaluating different rhizome sizes and spacing combinations under field conditions, the research aims to establish a practical configuration that can maximize both yield and profitability for turmeric growers.

II. REVIEW OF LITERATURE

Turmeric cultivation has been widely studied, but many investigations focus on isolated factors rather than combined

influences. Earlier work by Hegde et al. (2002) highlighted the importance of seed size, noting that larger rhizomes typically sprout earlier and establish stronger plants. Similar patterns have been observed in ginger and other rhizomatous crops. Patel and Chauhan (2014) found that seed pieces with greater stored carbohydrates supported better shoot emergence and early vigor. Spacing also influences several physiological processes. Singh and Verma (2013) demonstrated that wider spacing improves light penetration and minimizes mutual shading, which enhances photosynthetic efficiency. Kurup et al. (2017) emphasized that planting geometry influences canopy temperature, pest pressure, and soil moisture dynamics. These microclimatic changes ultimately affect rhizome development and yield distribution.

Interaction studies offer a more complete picture. Sharma et al. (2018) observed that yield differences become more pronounced when seed size and spacing are manipulated simultaneously. Their findings showed that medium or large rhizome sizes combined with moderate spacing produced superior finger rhizome yield and better dry recovery. Nair and George (2010) noted that too-close spacing can limit nutrient uptake, while too-wide spacing can reduce field-level yield despite increased weight per plant.

Economics has emerged as a critical angle in recent literature. Meena and Bairwa (2020) highlighted that the most productive treatment is not always the most profitable. Large rhizomes may produce heavy clumps but significantly raise cultivation cost, reducing benefit–cost ratio. Lal et al. (2021) argued that profitability should guide agronomic recommendations, especially for small-scale farmers. Quality parameters such as curcumin content have also been linked to crop vigor. Ghosh (2016) reported that healthier plants with strong vegetative growth tend to synthesize higher levels of curcuminoids. This connects rhizome size and spacing with post-harvest quality, reinforcing their importance in crop management.

Despite these findings, literature still lacks unified recommendations suitable for diverse field environments. Farmers require clear, practical guidelines supported by integrated studies. The present research contributes to this need by examining growth, yield, quality, and economics together under a unified experimental design.

III. MATERIALS AND METHODS

This study was carried out on an agricultural research farm with sandy-loam soil, medium organic carbon, and good drainage. Turmeric grows best in soils that don't hold excess water, so these conditions worked in our favor. The area stays warm through most of the season and gets a moderate monsoon, which together create a steady environment for plant growth and rhizome development. Before planting, the field was ploughed twice, then harrowed to get a smooth tilth, and finally shaped into raised beds about 20 centimeters high to keep the soil aerated and prevent water from collecting around the plants.

The experiment focused on two simple but important choices farmers make: the size of the rhizome they plant and the spacing they use. Rhizome size was grouped as small (15–20 g), medium (30–35 g), and large (45–50 g). Planting geometry followed three spacing patterns: 30 × 30 cm, 45 × 30 cm, 60 × 30 cm. These combinations formed a clean 3 × 3 factorial layout that allowed us to observe how size and spacing influence the crop when put together.

A Randomized Block Design with three replications was used so that natural field variation wouldn't affect the results too much. Each plot was 3 m × 2 m. Before planting, we mixed 25 t/ha of well-rotted farmyard manure into the soil to improve its structure and support good microbial activity. All seed rhizomes were treated with a mild fungicide to reduce early infections and give the crop an even start. Planting was done by hand at a depth of 5–6 cm. The field received its first irrigation right after planting, and further irrigations were given depending on soil moisture and rainfall. Earthing-up was done twice to support the plants and provide loose soil around the developing rhizomes. Nutrient management followed the recommended schedule of 120 kg N, 50 kg P, 100 kg K per hectare, applied in split doses. Weeds were removed manually whenever needed to prevent them from competing with the crop. Throughout the season, we recorded a series of observations that captured both early growth and final performance. These included sprouting percentage, plant height, number of tillers per clump, leaf area index, fresh rhizome yield, mother-to-finger rhizome ratio, dry recovery percentage, and curcumin content. Together, these measurements helped build a clear picture of how each treatment behaved in the field.

All the data were analyzed using standard statistical software. We used ANOVA to test whether the treatments differed from one another, and whenever differences were significant, we compared the means using the critical difference at the 5 percent level to make sure our interpretations were solid.

IV. RESULTS AND DISCUSSION

➤ *Early Growth Performance*

The differences in early growth showed up almost immediately. Large rhizomes sprouted sooner and pushed out taller plants during the first few weeks, powered by their bigger reserves of stored carbohydrates. They simply started with more fuel, so their initial growth looked stronger and more confident. Medium-sized rhizomes followed closely. They sprouted well and built healthy early foliage, narrowing the gap with the larger ones more than expected. This hints at an important point: once a rhizome reaches a certain size, the extra storage doesn't translate into equally large gains in early growth. Medium rhizomes already carry enough stored food for a solid start, so the additional weight in large ones offers only a marginal advantage. In the field, the pattern was clear. Large rhizomes led early, medium rhizomes kept pace, and the smallest pieces lagged as shown in fig.1. The early momentum created by seed size shaped the rest of the season, choosing rhizome size a practical and economic decision as much as a biological one.

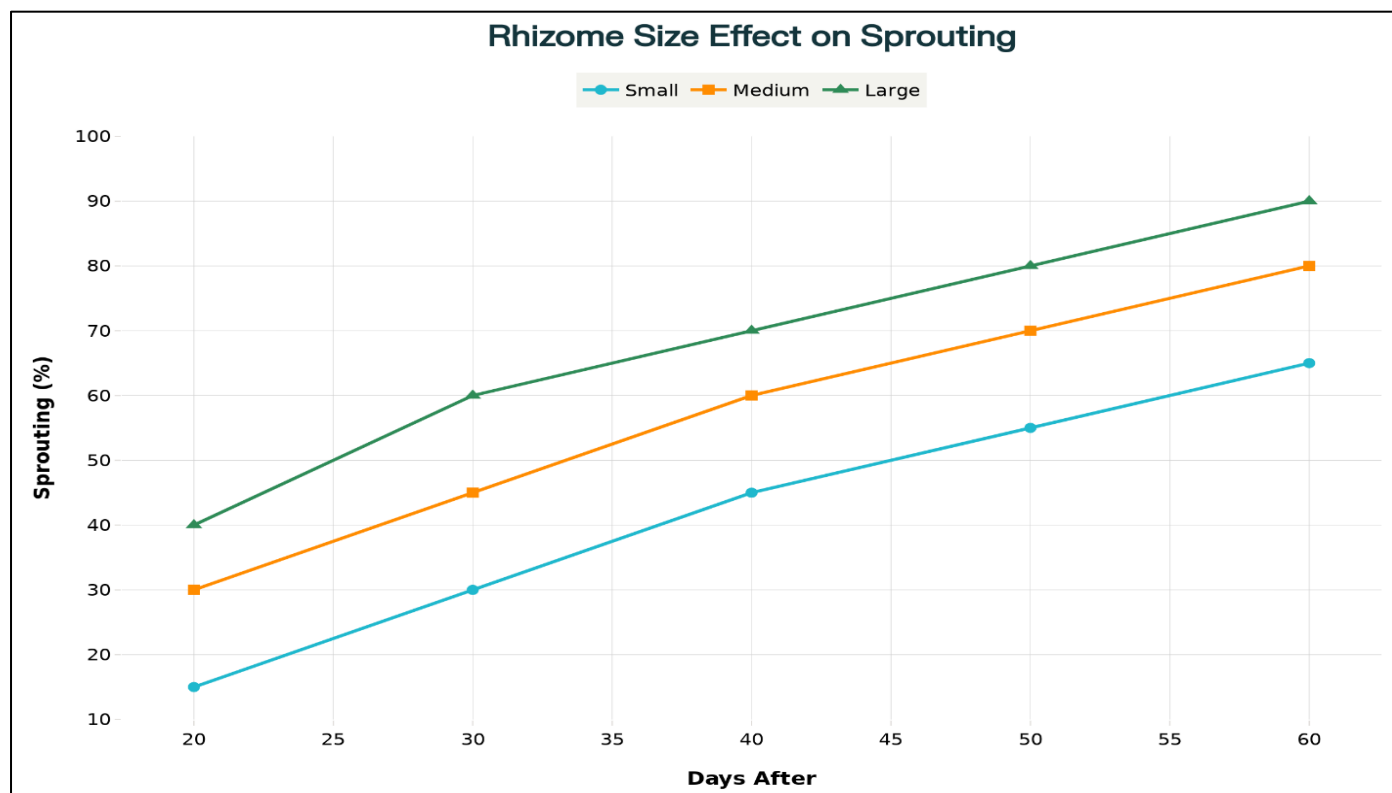


Fig 1 Effect of Rhizome Size on Sprouting Percentage and Early Plant Vigor

➤ Influence of Planting Geometry

Planting geometry had a noticeable effect on how the crop grew and how the canopy developed over time. When plants were given more space, they simply had more room to expand. You could see it in the way the leaves widened and the clumps became more open, allowing light to move deeper into the canopy. Wider spacing also reduced root-level competition, so each plant had better access to moisture and nutrients. This usually encouraged stronger tiller formation and a more robust-looking plant.

But here's the interesting part: even though individual plants performed better under wider spacing, that didn't automatically translate into higher yield per hectare. The closer spacing (30 × 30 cm) packed more plants into the same area. Each clump stayed smaller, and the leaves didn't spread as freely, but the overall number of productive plants was higher. Because of this higher plant population, the total yield per unit area actually increased, even though the performance of each individual plant was slightly reduced. In practical terms, wider spacing helped the plants express their full growth potential, but tighter spacing made better use of the field. The balance between individual plant performance and total plant density explains why closer spacing often ends up producing more yield when measured on a field scale.

➤ Yield Attributes

When we looked closely at the yield components, the differences between treatments became easy to see. Large rhizomes naturally gave the plants a head start. They sprouted with more energy, built thicker clumps, and ended up producing heavier mother and finger rhizomes on each plant. If you judged performance plant-by-plant, the bigger seed

pieces clearly looked impressive. You could almost tell from the field itself—those plants simply carried more weight underground.

But the picture shifted when medium-sized rhizomes entered the comparison. Even though each plant didn't grow quite as massive as those from the large rhizomes, the medium pieces struck a better balance. They sprouted consistently, formed healthy rhizome clusters, and, because they cost less and allowed slightly better plant density, their overall contribution to yield was more efficient. In other words, medium rhizomes didn't chase maximum size per plant; instead, they delivered reliable performance across the field, which turned out to be more valuable.

Spacing added another layer to the story. The 45 × 30 centimeter geometry stood out as the sweet spot. It gave the plants enough room to spread their leaves and develop decent-sized rhizomes, yet it kept the number of plants per unit area high enough to push the total yield upward. Wider spacing looked good for individual plants, but couldn't match the overall field-level production. Closer spacing packed too many plants together and restricted airflow and canopy spread, which eventually tightened the yield per plant. The 45 × 30 centimeter spacing didn't force the crop to choose between quantity and health. It supported steady growth, maintained good canopy structure, and delivered a high total yield across the field. When combined with medium-sized rhizomes, the yield attributes lined up in a way that felt both practical and dependable—strong enough per plant and efficient enough per hectare.

In simple terms, the best results didn't come from pushing plants to extremes, as shown in fig.2. They came from giving the crop the right inputs in the right proportions,

allowing each plant to perform well without overcrowding or overspending.

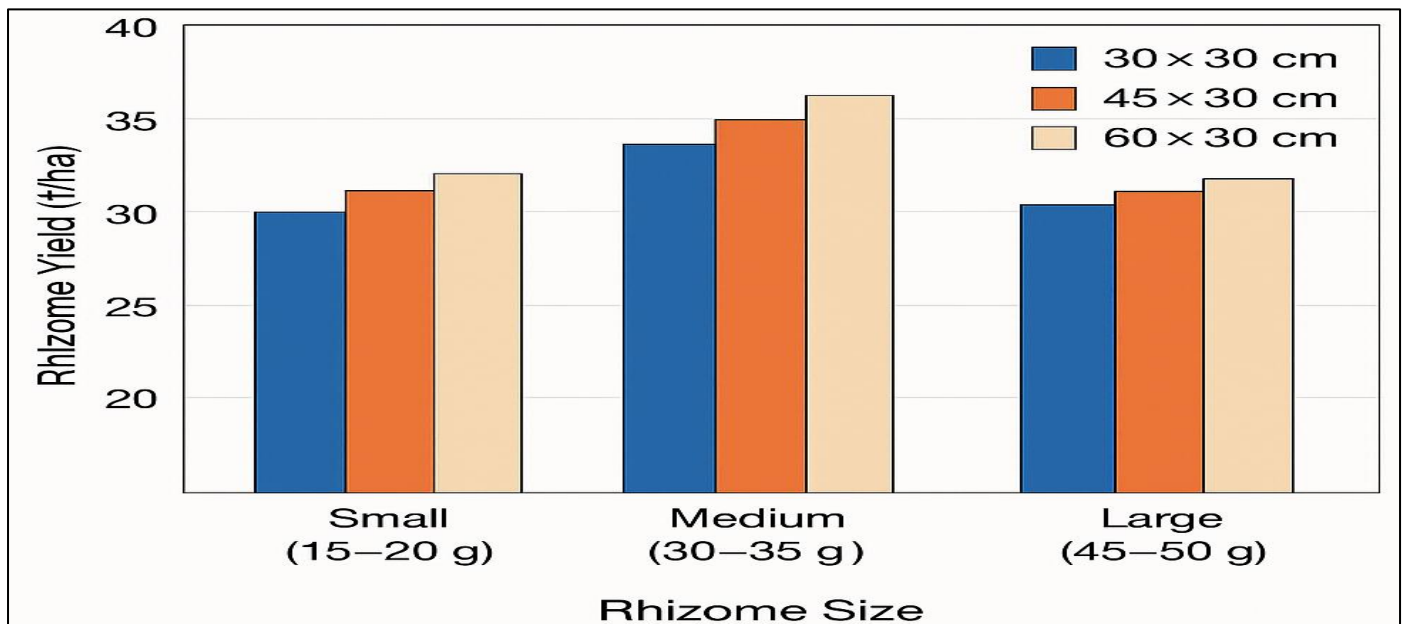


Fig 2 Rhizome Yield Response to Interaction of Rhizome Size and Spacing

➤ Curcumin Content and Quality

Curcumin levels showed a gentle upward trend with stronger plant growth. Plants from larger rhizomes, which produced fuller canopies and more vigorous shoots, carried slightly higher curcumin content. Their stronger photosynthesis and nutrient uptake likely helped them build a bit more of the compound.

Even so, the difference wasn't dramatic. Medium-sized rhizomes also produced good curcumin levels, and even the

smaller ones stayed within an acceptable quality range, as shown in Fig. 3. In other words, vigor helped, but it wasn't the only factor shaping curcumin content. The overall takeaway is simple: while larger rhizomes offered a small advantage, quality stayed stable across treatments. Farmers don't need oversized seed pieces just to maintain curcumin levels; balanced growth and good crop management matter just as much.

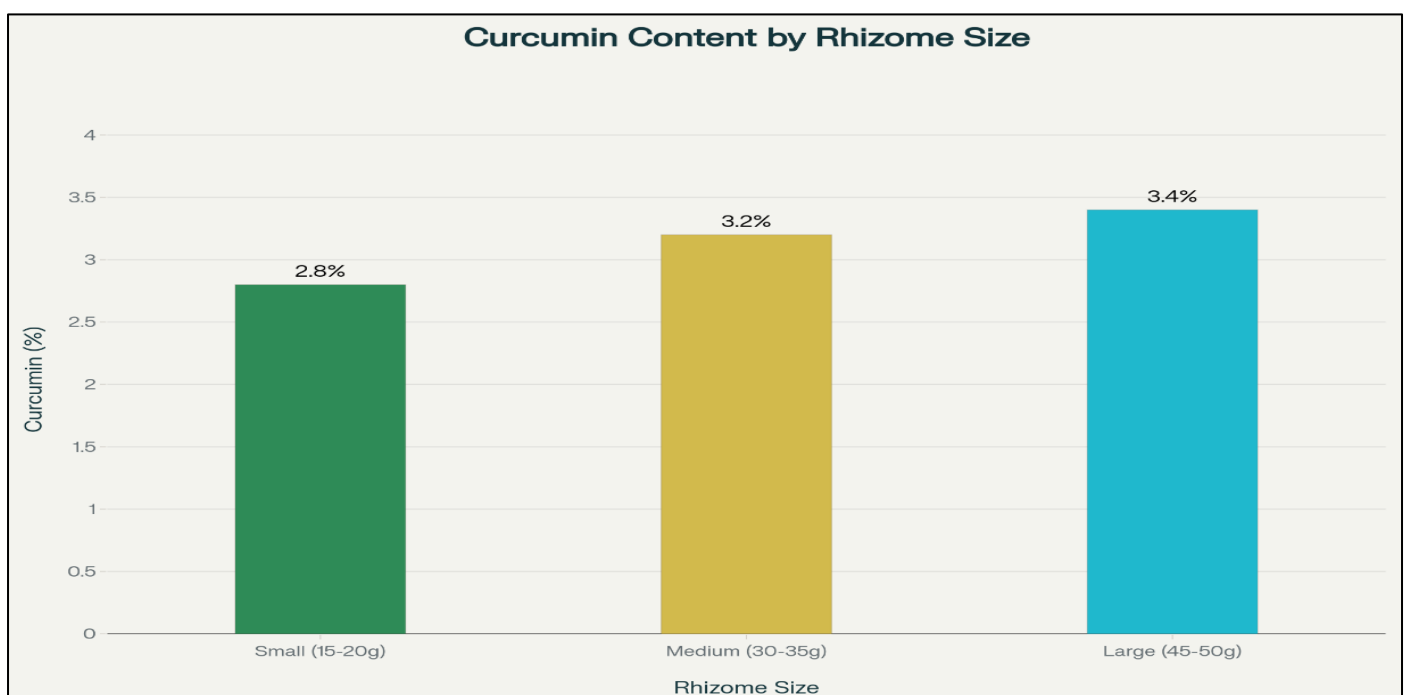


Fig 3 Curcumin Content Across Different Rhizome Size Treatments

➤ Economic Analysis

When the numbers were worked out, one pattern stood out pretty clearly. The combination of medium-sized rhizomes with the 45 × 30 centimeter spacing delivered the best overall profit. The yield was strong, the cost of planting material stayed reasonable, and the final returns made the most sense from a farmer's point of view. It struck a balance that neither pushed costs too high nor limited production too much.

Large rhizomes did give a slight edge in yield, but the catch was their price. Bigger seed pieces cost more, and that extra investment didn't translate into enough additional income to justify the higher expense. Although the plants looked impressive in the field, the economics didn't support choosing the largest size.

On the other hand, the smallest rhizomes didn't pull their weight. Their lower sprouting vigor and weaker early growth dragged down the overall yield. By the time everything was tallied, the savings from buying smaller seed pieces weren't nearly enough to compensate for the reduced harvest. What this really means is that there's a sweet spot—moderate seed size and moderate spacing—which gives the crop room to grow without inflating production costs. This matches what earlier studies have been saying as well: you don't need the biggest seed pieces or the widest spacing to make the crop profitable. You just need the right balance, and in this case, the medium-sized rhizomes at 45 × 30 centimeters hit that balance almost perfectly.

V. CONCLUSION

When you step back and look at the entire study—the growth patterns, the yield numbers, the cost calculations—the message is straightforward. The simple choices farmers make at the very beginning, like the size of the rhizome they plant and the spacing they follow, can shape the entire outcome of a turmeric crop. Medium-sized rhizomes, weighing about 30 to 35 grams, consistently showed the right mix of strength and efficiency. They sprouted well, built healthy clumps, and produced good-quality rhizomes without driving up the cost of planting material. Pairing them with a spacing of 45 × 30 centimeters created a setup where each plant had enough room to grow, but the field also carried enough plants to make the harvest worthwhile. It's that sweet spot where growth, yield, and economics all line up.

The larger rhizomes did bring in slightly higher yields, but the extra money spent on them didn't pay back enough to make them a smarter choice. The smaller ones, on the other hand, simply didn't have the strength to deliver the kind of yield farmers need. So the middle path—both in seed size and spacing—turned out to be the most practical and profitable. What this really means for farmers is encouraging. You don't need to invest in oversized planting material or push for very wide spacing to get a good crop. A balanced, thoughtful choice can raise productivity, maintain quality, and still keep input costs under control. Medium rhizomes at 45 × 30 centimeters offer a combination that works well in the field and makes sense in the ledger. In short, the study points

toward a strategy that is not only effective but also easy to adopt, helping farmers improve their turmeric production with confidence.

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