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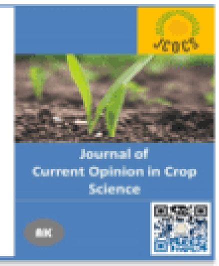

RESEARCH ARTICLE

Effects of growing media, and cultivar on the development and quality of mango rootstock

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ABSTRACT

In a successful mango plant establishment, the choice of a strong and healthy rootstock is crucial for subsequent propagation. An experiment was conducted during the 2023 mango seedling growing season at the Sokoine University of Agriculture horticultural sections in Morogoro, Tanzania. The study aimed to evaluate the influence of different growing media and cultivars on the growth and development of quality-certified mango rootstock plants. Ripe local mango fruits were collected from neighbouring farms and sown in polyethylene bags containing a mixture of forest soil, sand, farmyard manure, and sawdust. The experiment followed a randomized complete block design with three replications. Data collected included days to 50% germination, seedling mortality, seedling height, stem girth, and chlorophyll content (measured using the SPAD Unit). Results indicated that using sindano cultivars as rootstock significantly reduced days to germination and increased germination percentage (89.5%) while minimizing seedling mortality (2). Additionally, forest soil contributed to maximum seedling height (43.95 cm), stem diameter (0.52 cm), and chlorophyll content (40.05). The interaction between cultivar and growing media significantly influenced various mango seedling growth parameters. Bongwa cultivars planted in growing media composed of forest soil alone or combined with farmyard manure and sand produced high-quality, certifiable mango rootstock plants.

Keywords: cultivar, growing media, mango seedlings, rootstock.

Mango (*Mangifera indica*) stands out as one of the most widely cultivated tropical fruits globally, owing to its economic value, nutritive richness, and delightful flavour. Mango ranks among the top five fruits in terms of volume production worldwide (FAO, 2013). To sustain productivity, mango crops rely on robust cultivars and advanced propagation techniques. Nutrient-packed mangoes contribute vitamins (A and C), minerals, and antioxidants to our diets. Tanzania holds the 16th position in mango production, yielding approximately 437,000 tons annually (FAO, 2020). India leads the world, followed closely by China. Nigeria and Egypt spearhead mango production in Africa. Tanzanian mango cultivation predominantly features traditional cultivars (constituting 95% of total production). Introduced cultivars (e.g., Apple, Palmer, Balibo, Haden, Keitt, Kent, Van Dyke, Tommy Atkins) make up the remaining 5%. Traditional mangoes, while unsuitable for processing or export due to fiber content and irregular shape, find local markets. Introduced cultivars boast superior market traits. Improved mango trees result from grafting traditional cultivars, ensuring adaptability to local conditions.

Mango fruits are consumed in various forms: raw, canned, or as juice, providing essential nutrients, dietary fibers, and vitamins. According to the Food and Agriculture Organization's Cooperative Statistical Database (FAOSTAT, 2009), processed mango products dominate the global market, with popular varieties like "Kent," "Alfonso," and "Tommy Atkins." Interestingly, the green, unripe part of the mango finds its way into curries, sharbats, and pickles. Mango plants are propagated asexually through grafting to form a complete seedling. Each part of the plant is composed of the rootstock, which provides the root system, and the scion, which forms the tree canopy. Compared to different mango-growing nations, good mango seedling production practices and certifications of the produced seedlings are poorly practiced in Tanzania, and therefore the quality of the traded rootstocks and grafts is in doubt. (Mkenda, 2011) reported that varieties of improved mango seedlings distributed to farmers for commercial production are said to be limited, and even the accessibility to the few available, healthy, and suitable rootstock for mango seedlings is also said to be too limited.

A rootstock plays a great influence on the vigor of the seedling health, longevity, and productivity of the scion variety attached to it. Gebresmon et al. (2021) highlighted that the quality and eventual mango fruits to be produced are also said to be affected by the rootstock. Therefore, it is quite important to identify and develop good propagation practices that raise good-quality rootstock that can be certified by the respective regulatory controls to ensure high productivity, quality of the mango produce, and sustainability. Nursery growing media is also an important input for health, good uniformity, vigour, and the general quality of rootstock (Gebresmon et al., 2021). Apart from acting as an anchorage for rooting systems, it also supplies essential nutrients necessary for the health and vigorous growth of the seedling. Therefore, this study aimed to develop good practices for quality, certifiable mango rootstock production by evaluating the influence of cultivars and growing media.

MATERIALS AND METHODS

Description of the study area

This experiment was conducted from December 2022 to May 2023 at the Sokoine University of Agriculture, horticultural section nurseries in Morogoro, Tanzania. The area is located close to Mbuyuni Street, Morogoro Urban, and it lies on the slopes of the Uluguru Mountains, at an altitude of 500–600 meters above sea level, with the geographical coordinates of 6° 51' 5" S latitude and 37° 39' 25" E longitude. The area receives an average annual rainfall of between 600 and 1000 mm, with the annual temperature ranging from 18 °C to 30 °C.

Experimental Design and Materials

The experiment was conducted in a randomized complete block design (RCBD) with three replications. The experiment involved four local mango cultivars, namely sindano nyeupe (C1), sindano nyeusi (C2), mviringe (C3), and bongwa (C4), that were collected from neighbouring farm orchards. Mango seeds were prepared by pealing the seed coat to remove the seed and then sown in polyethylene bags of 40 cm x 25 cm size. The collected mango seeds were ripened, healthy, and of the current season. A growing media was composed of the mixture of forest soil, sand, farmyard manure, and sawdust at the ratio of M1, forest soil: sand: FYM: sawdust (1:1:1:1), M2, forest soil: FYM: sawdust (1:1:1), M3, forest soil: sand: sawdust (1:1:1), M4, forest soil: sand: FYM (1:1:1), and M5 = forest oil alone. The two-growing media, forest soil and sand, were sourced from the horticulture nurseries unit, while sawdust and farmyard manure were from the carpentry workshop and the University animal farm.

Data collection and analysis

Data collected were days to 50% germination, number of seedling deaths, seedling height (cm), number of leaves, seedling girth (mm), tap root length (cm), root girth (mm), and chlorophyll content that was measured using the SPAD Unit. The descriptive analysis was done to analyze all the collected data where R statistical software was used, and mean values were analyzed by using analysis of variance and least significant difference tests at P≤0.05.

RESULTS

Influence of main effects (growing media and mango cultivars) on mango rootstock growth and developments

The influence of growing media and mango cultivars on the growth parameters of mango seedlings are presented in Table 1. The number of days to 50% mango seed germinations was found to depending on the cultivars. Sindano nyeupe (C1) and sindano nyeusi germinated earlier than mviringe (C3) and bongwa (C4). The earlier two cultivars (sindano nyeupe and sindano nyeusi) took 21dyas to 50% mango seed germination, while the latter two (mviringe and Bongwa cultivars) took 23 days. This shows that sindano nyeupe and sindano nyeusi significantly germinate quickly as compared to mviringe cultivars and bongwa cultivars. These observations are in contravention of the research by (Minja et al., 2017) in the Pwani region of Tanzania, who observed and concluded that sindano cultivars had slower and lower percentage germinations than another tested local cultivar. The reason for this difference may be due to environmental factors. Also, the performance of cultivars conditioned the number of seedling deaths. The highest number of seedling deaths was observed for the mviringe cultivar (C3) as compared to sindano nyeusi (C2) the least number of seedling deaths (2). The difference on seedling death among local mango cultivars may be influenced by various factors, including genetic traits, environmental conditions, and the overall health and resilience of the cultivar. Given all the management and environmental factors kept constant, some cultivars respond slowly to the management and the environment, and some may undergo stunt growth and eventually die, as for mviringe cultivar (C3).

Seedling heights responded differently among cultivars depending on the growing medium and cultivar. The highest seedling height of 43.93 cm was recorded for forest soil (M5), and the lowest height of 31.71 cm was for growing media composed of forest soil, sand, and sawdust (M3). Variation in growth rate indicated higher contributions of the growing media to seedling height. The results are in line with Gawankar et al. (2020) who reported the ability of forest soil mixed with FYM to influence kokum and mango seedling height significantly. Essential nutrients in forest soil play a crucial role in seedling growth by providing essential elements that support various physiological processes for plant development. After every two months, seedling heights were recorded, and different cultivars responded differently to seedling height. Bongwa cultivar (C4) gave the tallest (37.9 cm) seedlings, while mviringe cultivar (C3) gave the shortest (33.58 cm). This shows that, in the study area, the mviringe cultivar (C3) on its own responds slowly to growth height as compared to other cultivars, and thus it is likely to easily fall below the certification standards for minimum rootstock height (15 cm). To ensure the production of certifiable rootstocks, it's important to consider producing seedlings with the heights prescribed by the certification standard. Thokchom et al. (2019) emphasized that growth characteristics, including leaf area, internodal length, root length and diameter, and fresh and dry weight of shoots and roots, are influenced by both rootstock height and the height of the grafting point. This finding aligns with earlier research by Singh (2001), who observed that plant growth was significantly impacted by grafting height. Specifically, grafting at 15 cm resulted in the highest growth in mango, apple, and crab seedlings. However, Sampaio (1993) reported a different outcome for Valencia orange plants, where vegetative development was not affected by budding heights at 15, 25, and 35 cm, respectively.

Seedling stem diameter was also influenced by growing media (P≤0.05). The highest and lowest stem diameter was recoded forest soil media (M5) (0.5 cm), and the media composed of forest soil, sand, and sawdust (M3). It is essential to consider using growing media that have the maximum stem diameter to ensure the development of certifiable rootstock and, subsequently, grafting success. Nikam et al. (2021) investigated the impact of rootstock girth in softwood grafting on the growth and survival of various mango varieties. Their findings indicated that a rootstock girth of 0.5 cm had higher survival rates and improved growth of mango grafts, comparable to 0.7 cm rootstock girth. Singh et al. (2014) reported similar observations, emphasizing thicker rootstocks to facilitate optimal suction flow and sustained nutrient supply from stored reserves, thereby enhancing the graft union process.

The study on seedling vigour revealed a significant difference (p≤0.05) attributed to the influence of growing media, with a minor variation due to cultivars. Among the media types, forest soil (M5) significantly contributed to seedling vigour, accounting for 25.7% of the Seedling Vigor Index (SVI). In contrast, the combination of forest soil, sand, sawdust, and farmyard manure (M1) contributed the least (17.7%) to SVI. These findings highlight the potential impact of forest soil (M5) on enhancing seedling vigour, potentially leading to robust and healthy certified seedlings.

Notably, Gawankar et al. (2020) emphasized that the availability of strong and vigorous seedlings as rootstock is crucial for successful nursery programs. Additionally, media formulations containing forest soil and farmyard manure are known to improve nutritional status, enhance photosynthetic activity, and promote the accumulation of plant-stored materials. This has a positive effect on seedling growth aligns with Gholap and Polara (2015) report.

The chlorophyll content is influenced by both growing media and cultivars. Among the media types, forest soil (M5) exerts the highest influence on chlorophyll content, while the combination of forest soil, sand, and sawdust (M3) has the lowest impact. Specifically, the bongwa cultivar (C4) exhibits the highest mean SPAD unit value (40.18), whereas sindano nyeusi (C2) has the lowest mean SPAD unit value (30.69). These observations suggest that bongwa cultivars, with their larger leaf area, accumulate higher chlorophyll content. Additionally, nutrients supplied by forest soil play a significant role in chlorophyll formation, enhancing photosynthetic activity. Chlorophyll serves as the plant's powerhouse, producing sugars that fuel growth and are stored in seeds, tubers, or stems. Increased chlorophyll production leads to greater sugar synthesis, ultimately promoting overall growth and development. Yilmaz et al. (2016) emphasized that variations in chlorophyll content depend on the specific cultivar and plant part.

Table 1. Mean differences of main factors (Media and cultivar) on different mango seedling growth parameters

FL	50% GM	GM (%)	NSD	SH (cm)	SG (cm)	VI (%)	LA (cm^2)	Chl (SPAD)
M1	22^{a}	81.71^{a}	4^{a}	31.71^{c}	0.48^{ab}	17.54^{b}	9.08^{ab}	36.78^{ab}
M2	21^{a}	86.92^{a}	3^{a}	34.64^{bc}	0.473^{b}	20.6^{ab}	10.0^{ab}	34.68^{b}
M3	23^{a}	78.87^{a}	5^{a}	33.04^{bc}	0.453^{b}	17.75^{b}	8.35^{b}	27.86^{c}
M4	22^{a}	83.91^{a}	4^{a}	36.45^{b}	0.478^{b}	21.7^{ab}	9.46^{ab}	37.68^{ab}
M5	23^{a}	77.31^{a}	5^{a}	43.93^{a}	0.519^{a}	25.71^{a}	10.81^{a}	40.05^{a}
Mean($\bar{X}$)	22	81.744	4.37	35.95	0.481	20.658	9.541	40.05
P (value)	0.54^{ns}	0.675^{ns}	0.66^{ns}	0.0003^{***}	0.025^{*}	0.086^{*}	0.12^{ns}	0.0001^{***}
C1	21^{ab}	85.41^{ab}	3^{ab}	34.97^{ab}	0.476^{a}	20.44^{a}	9.711^{a}	34.30^{bc}
C2	21^{b}	89.53^{a}	2^{b}	37.39^{ab}	0.488^{a}	23.24^{a}	9.33^{a}	30.69^{c}
C3	23^{a}	76.66^{ab}	6^{ab}	33.58^{b}	0.471^{a}	17.77^{a}	9.48^{a}	36.46^{ab}
C4	23^{a}	75.37^{b}	6^{a}	37.9^{ab}	0.488^{a}	20.66^{a}	9.64^{a}	40.18^{a}
Mean ($\bar{X}$)	22	81.7	4	35.96	0.48	20.53	9.54	35.407
P (value)	0.043^{*}	0.041^{*}	0.02^{*}	0.127^{ns}	0.67^{ns}	0.295^{ns}	0.97^{ns}	0.0007^{***}

FL-Factor level, 50%GM-Days to 50% seed germinations, GM %-Germination percent, NSD-Number of seedling death, SH-Seedling height, SG-Steam girth, VI-Vigor index, LA-Leaf area, Chl-Chlorophyl content, M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-forest soil+ farmyard manure+ sawdust, M3= forest soil+ Sand+ sawdust, M4= forest soil+ Sand+ farmyard manure and M5-forest oil alone), C-mango cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviringe, C4-Bongwa), ns-non significance, * indicates significance differences and the degree of significance differences increases with the increase in number of asterisk.

Two ways interactions affect mango rootstock growth and development

The results presented in Figure 1 indicate that cultivar responses regarding the time to 50% mango seed germination are influenced by the type of growing medium. Sindano nyeusi (C2) germinated (19 days) earlier in a mixture of forest soil, sand, sawdust, and farmyard manure (M1:C2). In contrast, the mviringe cultivar germinated late (28 days) in a medium consisting of forest soil, farmyard manure (FYM), sand, and sawdust (M1:C3).

Overall, both sindano nyeupe and nyeusi cultivars exhibited rapid germination responses across various growing media, outperforming the mviringe and bongwa. Forest soil and farmyard manure supply essential nutrients, while sand enhances porosity, allowing better air and water penetration into the seed. This favourable environment facilitates the emergence of the germinating embryo (Parasana et al., 2013). Among several factors, they concluded that a medium composed of forest soil, sand, and FYM resulted in the quickest days to germination (27 days) as compared to a medium composed of sand and vermicompost (35 days).

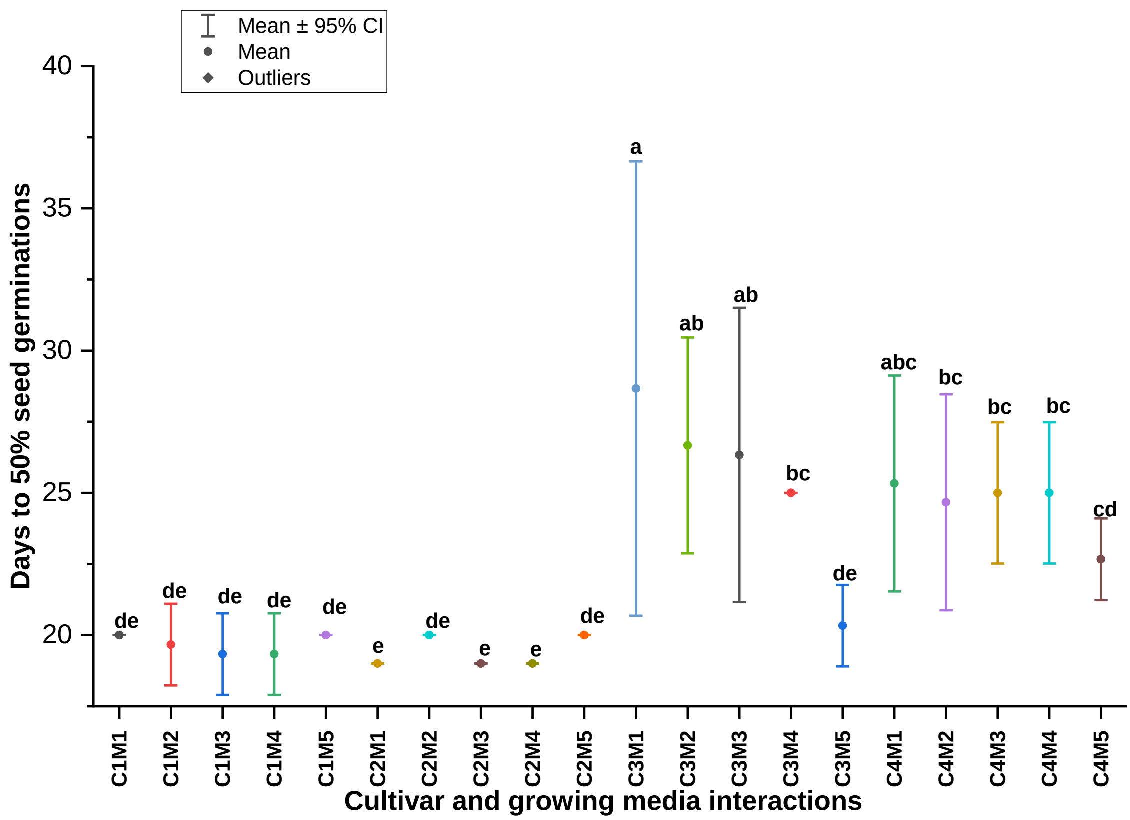

Figure 1. interaction effects of media and cultivar on days to 50% germinations.

M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-Forest soil+ farmyard manure +Sawdust, M3-Forest soil+ Sand+ Sawdust, M4-Forest soil+ Sand+ farmyard manure and M5-Forest soil alone, C-cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviring cultivar, C4-Bongwa cultivar).

Growing media effect on seed germination (%)

There is compelling evidence that cultivar germination percentages are influenced by growing media Figure 2 sindano cultivars consistently had the highest germination rates of up to 100%, regardless of the specific growing medium used. In contrast, the mviringe exhibited less favourable germination response, particularly when planted in a medium composed of soil, sand, and sawdust (M3). These findings underscore the importance of selecting appropriate nursery potting media in conjunction with suitable cultivars to enhance germination and overall productivity. Tekeste (2021) emphasized the pivotal role of media-cultivar interactions in improving germination outcomes. Sukhjit (2017) highlighted local mango cultivars, when paired with a growth medium containing a combination of forest soil and sand (in a ratio of 3:2:1), to exhibited superior seed germination, seedling growth, and establishment. Furthermore, Parasana et al. (2017) reported that a mixture of soil, sand, and farmyard manure (in a ratio of 2:1:1) to be the most effective in promoting better germination of mango seeds and subsequent growth of seedlings

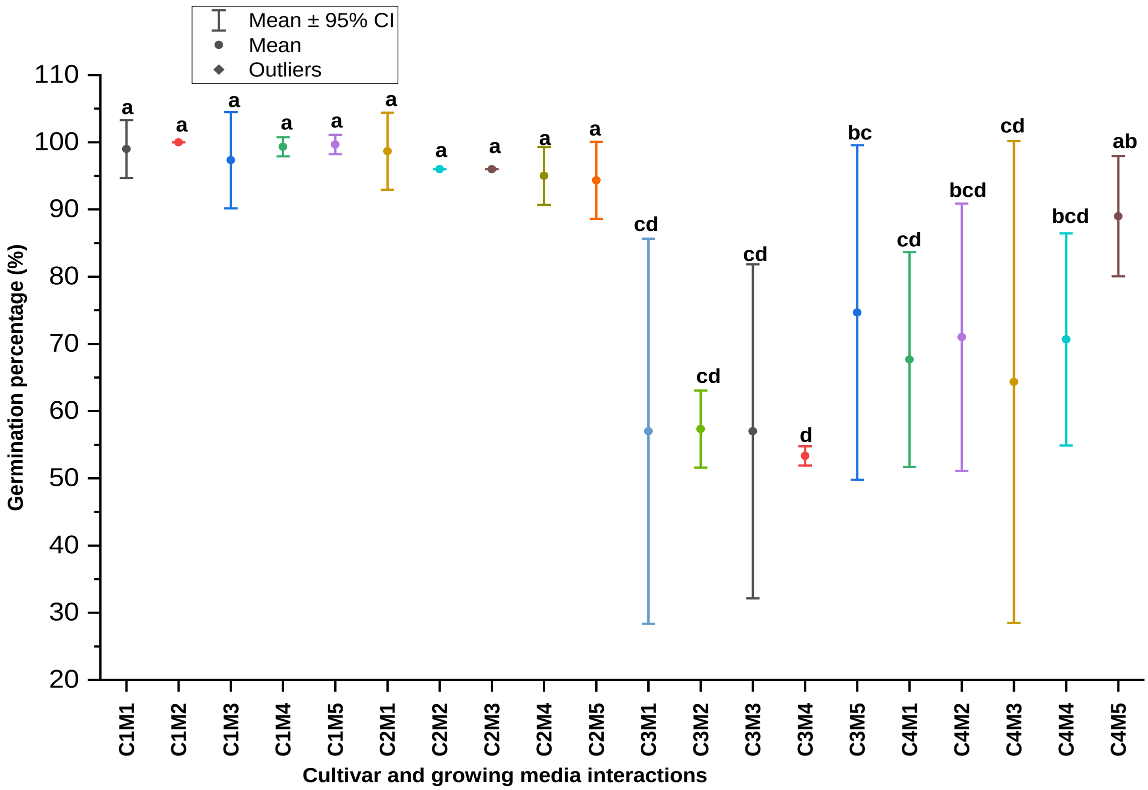

Figure 2. Interaction effects of media and cultivar on mango seed percentage germinations.

M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-Forest soil+ farmyard manure +Sawdust, M3-Forest soil+ Sand+ Sawdust, M4-Forest soil+ Sand+ farmyard manure and M5-Forest soil alone, C-cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviring cultivar, C4-Bongwa cultivar).

Influence of growing media and cultivars on number of mango seedling death

The data presented in Figure 3 suggests that the choice of growing media significantly influences seedling mortality across all tested cultivars. Notably, the mviringe cultivar (C3) exhibited higher mortality rates when grown in various media, except forest soil (M5), which reduced seedling deaths. In contrast, the sindano cultivars consistently showed lower mortality rates across different media types. The reduced moisture retention capacity associated with sand in the growing medium may contribute to stunted growth and seedling mortality. Forest soil (M5), lacking sand, resulted in the fewest seedling deaths for the mviringe cultivar (C3) compared to other media types. These findings align with Yury et al. (2019). Similarly, other researchers have reported that a 1:1 mixture of forest soil and farmyard manure (FYM) promotes the highest survival percentage in kokum seedlings, highlighting the effectiveness of FYM and forest soil in supporting seedling health. This observation is consistent with studies by Qyom (2011) and Gholap (2015) in mango seedlings.

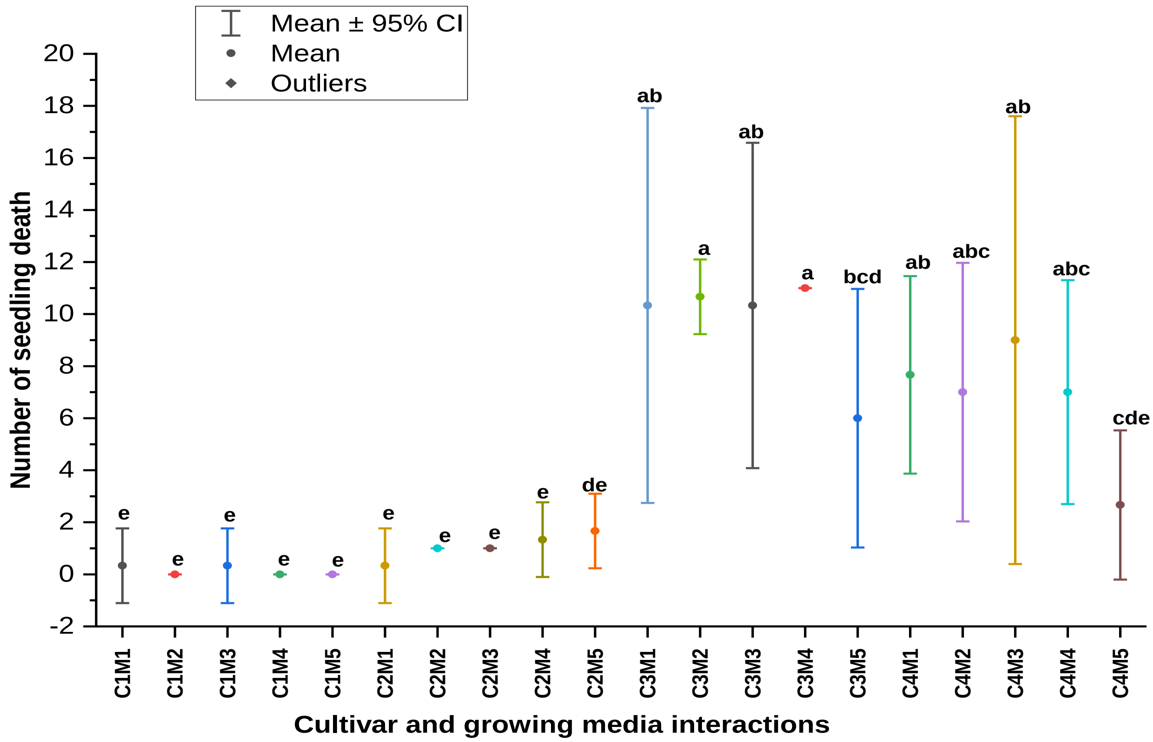

Figure 3. Interaction effects of cultivar and growing media on number of mango seedling death.

M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-Forest soil+ farmyard manure +Sawdust, M3-Forest soil+ Sand+ Sawdust, M4-Forest soil+ Sand+ farmyard manure and M5-Forest soil alone, C-cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviring cultivar, C4-Bongwa cultivar).

Effects of growing media and cultivars on mango seedling height (cm)

The height of seedlings differed significantly ($p \leq 0.05$) depending on the growing medium and cultivar. Bongwa grown in forest soil (M5) had the maximum seedling height of 52 cm, while mviringe grown in a media composed of forest soil, sand, and sawdust (M3) had the lowest seedling height of 24 cm. On the other hand, a growing media composed of forest soil, sand, and sawdust (M3) had a significantly lower impact on mviringe cultivar (C3) height. These combinations gave a mean height of 24.03 cm, significantly lower than other interaction treatment groups (Figure 4). Forest soil contributes to seedling height due to the role of soil microbes and high organic matter that increase aeration and availability of essential nutrients for plant growth and improve soil physical, chemical, and biological properties (Satodiya et al., 2016). Leua et al. (2013) reported the same for mango sown in growing media containing forest soil, sand, and FYM (2:1:1) which is in line with Panchal et al. (2014) for khirni seedlings grown in a media containing forest soil, cocopeat, and FYM at a ratio of 1:1:1, respectively.

The Tanzania mango seedling certification standards require the minimum length of rootstock to be 20 cm. This result reveals that all the cultivar and growing media interactions are above the rootstock height certifications cut point, with the combination group of bongwa cultivar and forest soil leading to the highest rootstock height, while the interactions group of mviringe cultivar (C3) and growing media 3 (C3:M3) are likely to fall below certification standards.

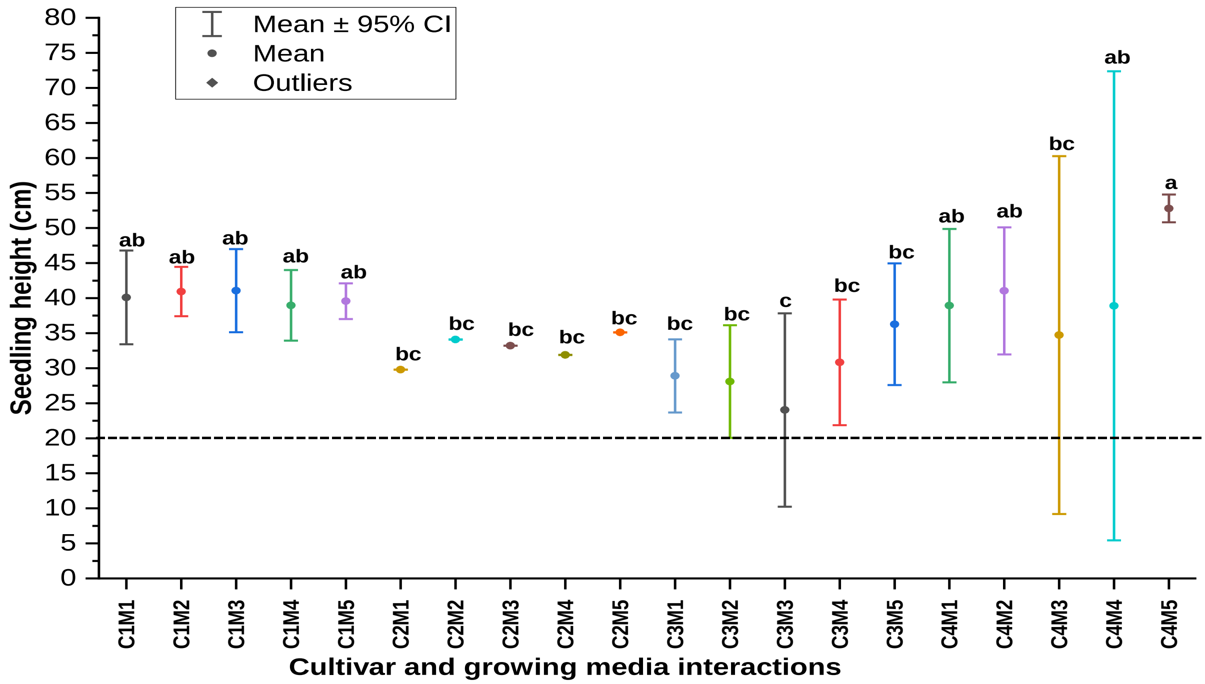

Figure 4. Interaction influence of cultivar and growing media on mango seedling height.

M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-Forest soil+ farmyard manure +Sawdust, M3-Forest soil+ Sand+ Sawdust, M4-Forest soil+ Sand+ farmyard manure and M5-Forest soil alone, C-cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviring cultivar, C4-Bongwa cultivar).

Mango seedling stem diameter (cm) as influenced by cultivar and growing media interactions

Seedling stem diameter was also found to depend on growing media and cultivar, and the level of dependence was significant at $p \leq 0.05$. Bongwa cultivar (C4) sown in forest soil media (M5) had the maximum height of rootstock stem diameter (0.62 cm), while mviringe cultivar (C3) sown in growing media containing forest soil, sand, and sawdust (M3) had the lowest rootstock stem diameter (0.39 cm) (Fig.5). Berhan et al. (2021) described the roles of the combination of different growing media (farmyard manure, forest soil, and sawdust) in the development and growth of mango seedlings. This supports the good performance of bongwa cultivar (C4) sown in forest soil media (M5) in terms of length, stem girth, root girth, and number of leaves.

Rachael et al. (2005) reported forest soil to contain organic matter, nutrients, and a diverse array of soil-dwelling microorganisms that enhance soil quality and nutrient uptake by plants. Similarly, Gawankar et al. (2020) emphasized the importance of obtaining healthy and vigorous seedlings for grafting purposes in nursery programs. The data on graftable seedling size, influenced by different media, revealed that the highest percentage of graftable seedlings occurred when using a mixture of forest soil and farmyard manure (FYM) in a 1:1 proportion.

Based on these findings, mango seedling certification standards (requiring a rootstock diameter of 0.6 cm) recommend using bongwa cultivars and/or sindano cultivars planted in a growing medium composed of forest soil alone or mixed with farmyard manure and sand.

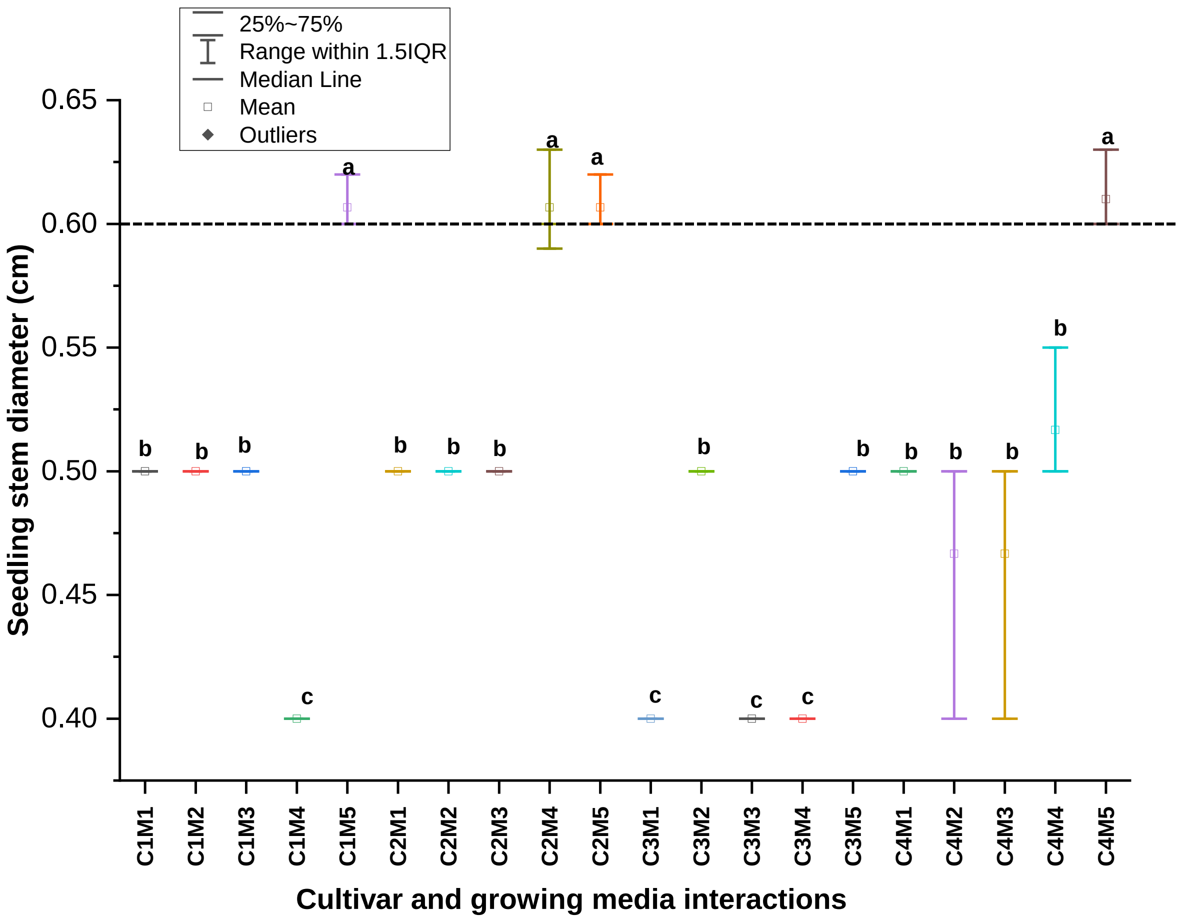

Figure 5. Interaction effects of media and cultivar on mango seedling stem diameter.

M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-Forest soil+ farmyard manure +Sawdust, M3-Forest soil+ Sand+ Sawdust, M4-Forest soil+ Sand+ farmyard manure and M5-Forest soil alone, C-cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviring cultivar, C4-Bongwa cultivar).

Mango seedling Chlorophyll Content (SPAD Units) as influenced by mango cultivar and growing media interactions.

Evaluation of chlorophyll content revealed significant variations ($p \leq 0.05$) among cultivars growing in different media. Bongwa cultivars sown in forest soil growing media (C4) (M5:C4) exhibited the highest mean SPAD value of 54.67, indicating a significant contribution of the media in increasing chlorophyll production. Sindano nyeupe (C1) sown in a growing media containing forest soil, sand, and sawdust (M3) (M3:C1) displayed the lowest mean SPAD value at 19.41, suggesting a significant reduction in chlorophyll content under these treatment conditions (Fig. 6). These emphasize the role of different media combinations in influencing chlorophyll production and photosynthetic activity in the seedling. Farah et al. (2022) investigated the impact of seed priming and growing media mixed with orchard soil (equivalent to forest soil) on seed germination percentages, germination index (GI), seedling vigor index (SVI), seedling height, stem diameter, and chlorophyll content. Similarly, Gawankar et al. (2020) found that the leaf area of kokum seedlings was influenced by growing media, with the forest soil + farmyard manure (FYM) mixture (1:1) resulting in maximum leaf area. The availability of nutrients in the growing substrate significantly affects leaf size, including dimensions such as leaf length and width. These ultimately impact solar radiation capture, which is crucial for photosynthesis and overall seedling growth. Notably, Bhardwaj (2014) reported similar findings in papaya seedlings.

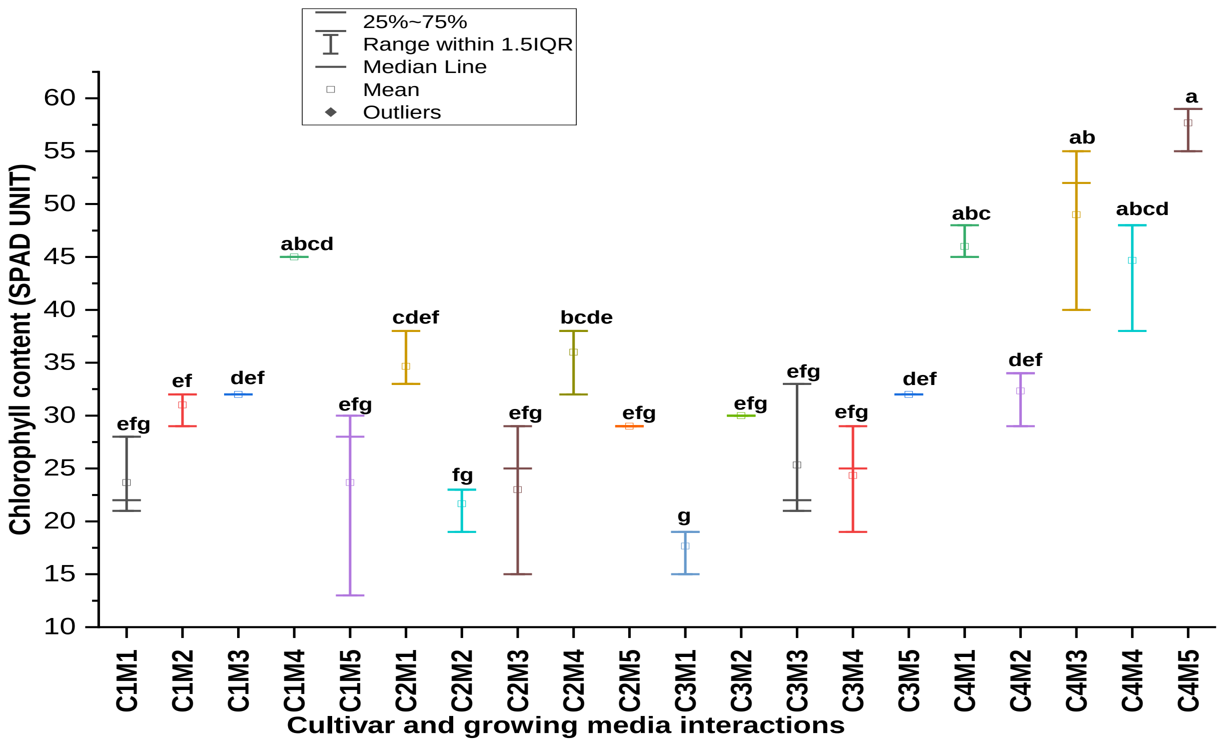

Figure 6. Interaction effects of media and cultivar on mango seedling chlorophyll content.

M-growing media (M1-forest soil+ sand+ sawdust+ farmyard manure, M2-Forest soil+ farmyard manure +Sawdust, M3-Forest soil+ Sand+ Sawdust, M4-Forest soil+ Sand+ farmyard manure and M5-Forest soil alone, C-cultivar (C1-Sindano nyeupe, C2-Sindano nyeusi, C3-Mviring cultivar, C4-Bongwa cultivar).

Principal Component Analysis of Parameters

Table 2 represents the eigenvectors for each variable in the principal component analysis (PCA) results. In PCA, eigenvectors are the directions in which the data varies the most and determine the principal components (PCs) of the data. Each eigenvector is associated with a specific PC.

PC1: The variables with high positive values in PC1 are positively correlated with each other in the data. In this case, "seedling girth and height (cm)" are positively correlated. On the other hand, "days to 50% germ," "seedling death," and "percentage germinations" have negative values in PC1, indicating a negative correlation with the variables listed earlier.

PC2: The variables with high positive values in PC2 are seedling death, percent germinations, and number of leaves. These variables are positively correlated with the data in this component. "Root girth and length (cm)" have negative values in PC2, indicating a negative correlation with the variables listed earlier.

Table 2. Eigenvectors extracted from parameters showing principal components analysis for all tested variables

Variable	PC1	PC2	PC3
Days 50% Germ	-0.287	-0.345	-0.081
Seedling death	-0.335	-0.294	-0.089

% Germination	0.335	0.294	0.089
Seedling height (cm)	0.337	-0.216	-0.267
No. of leaves	0.301	-0.200	-0.313
Seedling girth(cm)	0.321	-0.081	-0.145
Root girth(cm)	0.262	-0.005	0.411
Root Length(cm)	0.236	-0.316	0.153
Fresh weight(g)	0.160	-0.329	0.436
Dry weight(g)	0.154	-0.370	0.390

PC-Principal component Analysis table. The negative sign indicates presence of negative correlations between variables.

CONCLUSION

In the context of developing robust and healthy rootstock plants, our findings highlight specific considerations for different mango cultivars and growing media. Planting sindano nyeusi and sindano nyeupe in a medium composed of forest soil, farmyard manure, and sand, exhibit rapid and maximum germination percentages. Unlikely, bongwa which thrive when grown in forest soil alone. Apart from it yield high-quality, certifiable rootstock plants characterized by maximum stem diameter, seedling length, vigor, and chlorophyll content. It is therefore crucial to recognize that both cultivar selection and growing medium composition play integral roles in meeting the certification standards for mango rootstock plants.

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AUTHORS CONTRIBUTION

Mr. Bahati Charles Fungameza played a key role in research conceptualization, project administration, methodology design, data collection and analysis, drafting original content, resource provision, review, editing, and software management. Dr. Richard R. Madege contributed to research conceptualization, data curation, data visualization, software recommendations, review, editing, supervision, and validation. Dr. Yasinta Nzogela provided visualizations, supervision, review, and editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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