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Article

Planting Media Composition Drives Vegetative Establishment and Biomass Accumulation of Grapevine Stem Cuttings under Tropical Nursery Conditions

Wisnaningsih[1*], Moh Haris Imron S Jaya[2]

[1]Study Program of Mechanical Engineering, Faculty of Engineering, Universitas Saburai, Bandar Lampung, Indonesia
[2]Doctoral Program of Agricultural Science, Faculty of Agriculture, Universitas Padjadjaran, Bandung, Indonesia

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Abstract . The success of grapevine (Vitis vinifera L.) propagation through stem cuttings is strongly influenced by planting media quality during the nursery stage. Under tropical lowland conditions, unstable root-zone environments often reduce seedling vigor and biomass accumulation. Therefore, suitable manure-based media are needed to improve vegetative establishment and nursery efficiency. This study aimed to evaluate the effects of different manure-based planting media on vegetative growth and biomass accumulation of grapevine stem cuttings under tropical screen-house conditions in Bandar Lampung, Indonesia. The experiment was arranged in a randomized complete block design consisting of four treatments: M1 = sand + soil (1:1), M2 = sand + soil + cattle manure (1:1:1), M3 = sand + soil + goat manure (1:1:1), and M4 = sand + soil + chicken manure (1:1:1), with six replications. The results showed that the cattle manure-based medium consistently produced the best vegetative performance, increasing shoot length, leaf number, leaf area, fresh weight, and dry weight by 67.6%, 83.3%, 83.1%, 38.5%, and 40.4%, respectively, compared with the control treatment. Overall, cattle manure-based media provided the most favorable conditions for vegetative establishment and biomass accumulation of grapevine stem cuttings under tropical nursery conditions.

Corresponding Author :
Wisnaningsih
Study Program of Mechanical Engineering, Faculty of Engineering,
Universitas Saburai, Bandar Lampung, Indonesia
Email : wisnaningsih1968@gmail.com

1. Introduction

Grapevine (Vitis vinifera L.) is one of the most economically important horticultural crops cultivated worldwide for fresh consumption, processed products, and agro-industrial applications [1–3]. In tropical regions, including Indonesia, grapevine cultivation has continued to expand in response to increasing consumer demand and the development of commercial horticultural production systems [4-5]. In lowland tropical regions such as Lampung, the increasing interest in grapevine cultivation has intensified the need for efficient nursery technologies capable of producing vigorous and uniform seedlings under high-temperature environmental conditions [6]. The sustainability of grapevine production is highly dependent on the availability of healthy and vigorous planting materials capable of adapting rapidly during the early establishment phase [7].

Vegetative propagation through stem cuttings remains the most commonly applied propagation method in grapevine cultivation because it enables rapid multiplication while maintaining the genetic uniformity of superior cultivars [8]. The success of grapevine cuttings is closely associated with their ability to initiate roots, elongate shoots, develop leaves, and accumulate biomass during the nursery stage [7]. These physiological processes are strongly influenced by environmental conditions and planting media composition, which regulate water availability, nutrient supply, aeration, and root zone stability [9].

Planting media play a fundamental role in determining the success of nursery-stage propagation because they directly affect root establishment and vegetative growth performance [10]. An ideal propagation medium should possess balanced physical and chemical characteristics, including adequate porosity, sufficient water-holding capacity, favorable aeration, and stable nutrient availability [11]. Sand is commonly used to improve drainage and media porosity, whereas soil functions as a source of minerals and provides structural support for root development [12]. The incorporation of organic amendments, such as animal manure, further enhances media fertility, microbial activity, cation exchange capacity, and moisture retention, thereby improving vegetative establishment and seedling vigor [13].

Different animal manure sources may induce distinct vegetative responses depending on their nutrient composition, decomposition rate, and physicochemical properties [14]. Cattle manure is generally characterized by gradual nutrient mineralization and stable organic matter decomposition, which support sustained vegetative growth [15]. Goat manure contributes to improved aeration and organic matter accumulation [16], whereas chicken manure contains relatively high nitrogen concentrations and rapid nutrient release, which may alter root-zone balance under nursery conditions [17]. Under tropical environments, where high temperatures frequently accelerate organic matter decomposition and nutrient dynamics, understanding the interaction between manure-based media and vegetative establishment becomes increasingly important for developing efficient propagation system [18].

From the perspective of applied agricultural technology, optimization of planting medium composition is an important strategy for improving propagation efficiency, seedling quality, and sustainable nursery management systems. The utilization of locally available organic manure as a component of propagation media not only enhances vegetative growth but also supports environmentally friendly and low-input agricultural practices [19-20]. Formulating optimal propagation media technologies capable of improving root establishment, canopy development, and biomass accumulation is essential for supporting sustainable grapevine cultivation under tropical conditions.

Previous studies have reported the beneficial effects of organic amendments on rooting performance and vegetative growth in horticultural crops [21–23]. Yet, comparative knowledge on the physiological responses of grapevine stem cuttings to different manure-based planting media under tropical screenhouse conditions remains limited.

Most previous studies have focused primarily on individual growth parameters without comprehensively integrating vegetative and biomass responses using correlation-based approaches

[24-25] . Moreover, studies integrating vegetative growth responses with biomass accumulation to identify the principal determinants of grapevine cutting vigor under tropical nursery systems are still scarce. Consequently, the relationships among shoot growth, root development, canopy establishment, and biomass accumulation during early vegetative establishmentare still not fully understood.

Leaf development and biomass accumulation are particularly important indicators of cutting vigor because they directly reflect photosynthetic establishment and assimilate production during early vegetative growth [26]. Therefore, understanding the interactions among vegetative growth traits is essential for improving propagation efficiency and seedling quality in grapevine nursery systems. Accordingly, this study aimed to evaluate the effects of different planting media compositions enriched with several animal manure sources on vegetative growth and biomass accumulation of grapevine stem cuttings under tropical nursery conditions. Pearson correlation analysis was further employed to identify the principal vegetative traits associated with seedling vigor and biomass formation. The findings of this study are expected to contribute to the development of sustainable propagation media technologies for improving grapevine nursery production systems under tropical environments.

2. Materials and Methods

2.1. Study Site and Environmental Conditions

The experiment was conducted from March to June 2025 in a screen house located in Rajabasa, Bandar Lampung City, Lampung Province, Indonesia (5°22′16.9″ S; 105°13′30.5″ E), at an elevation of approximately 120 m above sea level. The study was carried out under tropical lowland environmental conditions during the nursery stage of grapevine propagation. In tropical lowland regions, high temperature and rapid organic matter decomposition frequently influence seedling establishment and media nutrient dynamics, making environmental management important during the propagation phase.

Environmental conditions inside the screen house were monitored throughout the experimental period. The average air temperature ranged from 28 to 34 °C, with relative humidity ranging from 65 to 85%. Natural light intensity inside the screen house ranged from approximately 18,000 to 32,000 lx during daytime conditions. The screen house provided partial shading and adequate air circulation while minimizing direct rainfall exposure, thereby creating favorable environmental conditions for vegetative establishment of grapevine stem cuttings.

2.2. Experimental Design and Planting Media Treatments

The experiment was arranged in a randomized complete block design (RCBD) consisting of four planting media treatments with six replications, resulting in 24 experimental units. The planting media treatments consisted of M1 = sand + soil (1:1) without manure addition, M2 = sand + soil + cattle manure (1:1:1), M3 = sand + soil + goat manure (1:1:1), and M4 = sand + soil + chicken manure (1:1:1).

All media components were thoroughly mixed until homogeneous before planting. The prepared media were transferred into polybags measuring 20 cm × 25 cm according to the experimental layout. The media were maintained under field-capacity conditions through regular irrigation during the experimental period. The planting media compositions used in this study were formulated based on commonly applied nursery practices and previous studies reporting the beneficial effects of manure-based media on vegetative establishment under tropical conditions [27]. Cattle manure has been widely reported to exhibit gradual nutrient mineralization and relatively stable physicochemical properties that may support sustained vegetative growth and root establishment during the nursery stage [28]. Goat manure is commonly associated with improved organic matter accumulation, enhanced media aeration, and favorable moisture retention, thereby contributing to better root-zone conditions for vegetative propagation [29]. In contrast, chicken manure generally exhibits rapid nutrient release and relatively high nitrogen availability under tropical environmental conditions, which may accelerate early vegetative responses but potentially alter nutrient balance within the propagation media [30].

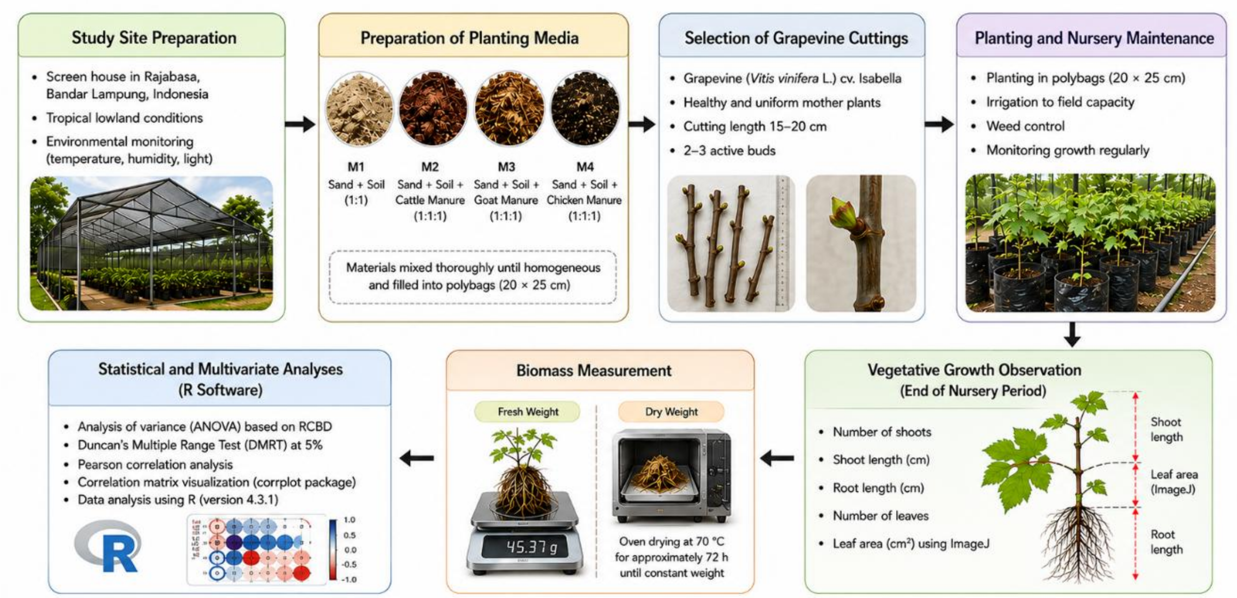

Figure 1. Experimental workflow illustrating the sequential stages of grapevine (Vitis vinifera L.) stem cutting propagation under different manure-based planting media treatments, including media preparation, planting, nursery maintenance, vegetative growth observations, biomass measurements, and statistical analyses.

In this study, we looked at how plants grew differently with various treatments. We based our findings on how well the plants grew and what we know about manure-based soil, not on detailed chemical tests. Figure 1 shows the steps we followed in our experiment. We prepared the soil, chose and planted cuttings, took care of the nursery, watched plant growth, measured plant weight, and did statistical analysis. This step-by-step process helped us collect data consistently during the nursery-stage experiment.

2.3. Plant Materials and Cutting Preparation

Stem cuttings of grapevine (Vitis vinifera L.) cv. Isabella were used as planting materials in this study. The cuttings were obtained from healthy and uniform mother plants maintained under field conditions. Stem cuttings measuring approximately 15–20 cm in length with 2–3 active buds were selected to minimize variability among experimental units (Figure 2).

Figure 2. Grapevine (Vitis vinifera L.) stem cuttings used as planting materials during the nursery-stage propagation experiment.

Prior to planting, all cuttings were visually inspected to ensure the absence of physical damage and disease symptoms. Each cutting was planted individually in a polybag containing the assigned planting medium. Routine nursery maintenance practices, including irrigation, weed removal, and environmental monitoring, were conducted uniformly throughout the experiment [31].

2.4. Growth Measurements

Vegetative growth observations were conducted at the end of the nursery period. The observed variables included number of shoots, shoot length, root length, number of leaves, leaf area, plant fresh weight, and plant dry weight.

Shoot length and root length were measured using a ruler and expressed in centimeters (cm). The number of shoots and leaves was determined manually by direct counting. Leaf area was measured using ImageJ software (National Institutes of Health, Bethesda, MD, USA). Fully expanded leaves were photographed and digitally analyzed to determine leaf area, which was expressed in square centimeters (cm^2). The use of ImageJ enabled accurate quantification of leaf surface area through image-based analysis [32]. Plant fresh weight was measured immediately after harvest using a digital analytical balance. Plant dry weight was determined after oven-drying the plant samples at 70 °C for approximately 72 h until constant weight was achieved [33].

2.5. Statistical and Multivariate Analyses

All data were subjected to analysis of variance (ANOVA) based on a randomized complete block design. When significant treatment effects were detected, mean separation was performed using Duncan's Multiple Range Test (DMRT) at the 5% significance level [34]. Pearson's correlation analysis was performed to evaluate the relationships among vegetative growth and biomass variables. Correlation coefficients were visualized using a Pearson correlation matrix to identify the principal traits associated with biomass accumulation and seedling vigor.

Statistical analyses were conducted using R software (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria). Pearson correlation matrices were generated using the "corrplot" package [35].

3. Results and Discussion

3.1. Effect of Planting Media on Vegetative Growth of Grapevine Stem Cuttings

The vegetative growth of grapevine stem cuttings was significantly influenced by planting media composition under tropical nursery conditions (Figure 3). In general, media enriched with organic manure promoted better vegetative establishment than the control medium without manure addition. Among all treatments, the medium containing sand, soil, and cattle manure consistently produced the best vegetative performance across shoot growth, root development, leaf formation, and canopy expansion. These findings indicate that cattle manure created a more balanced root-zone environment capable of supporting synchronized vegetative growth during early seedling establishment [36-37].

Although the number of shoots was not significantly different among treatments, clear differences were observed in other vegetative parameters. The chicken manure treatment produced the highest number of shoots (1.56 shoots plant^{-1}), whereas the control, cattle manure, and goat manure treatments produced 1.33, 1.39, and 1.28 shoots plant^{-1}, respectively. However, the increased shoot emergence observed under chicken manure treatment was not accompanied by proportional improvements in root growth, canopy establishment, or biomass accumulation. This result suggests that shoot emergence alone cannot fully represent the vigor of grapevine stem cuttings because early bud sprouting is strongly associated with endogenous carbohydrate reserves and hormonal activity within stem tissues [38]. In contrast, sustained vegetative development depends more on stable nutrient availability, root-zone balance, and efficient assimilate allocation under tropical nursery conditions [39].

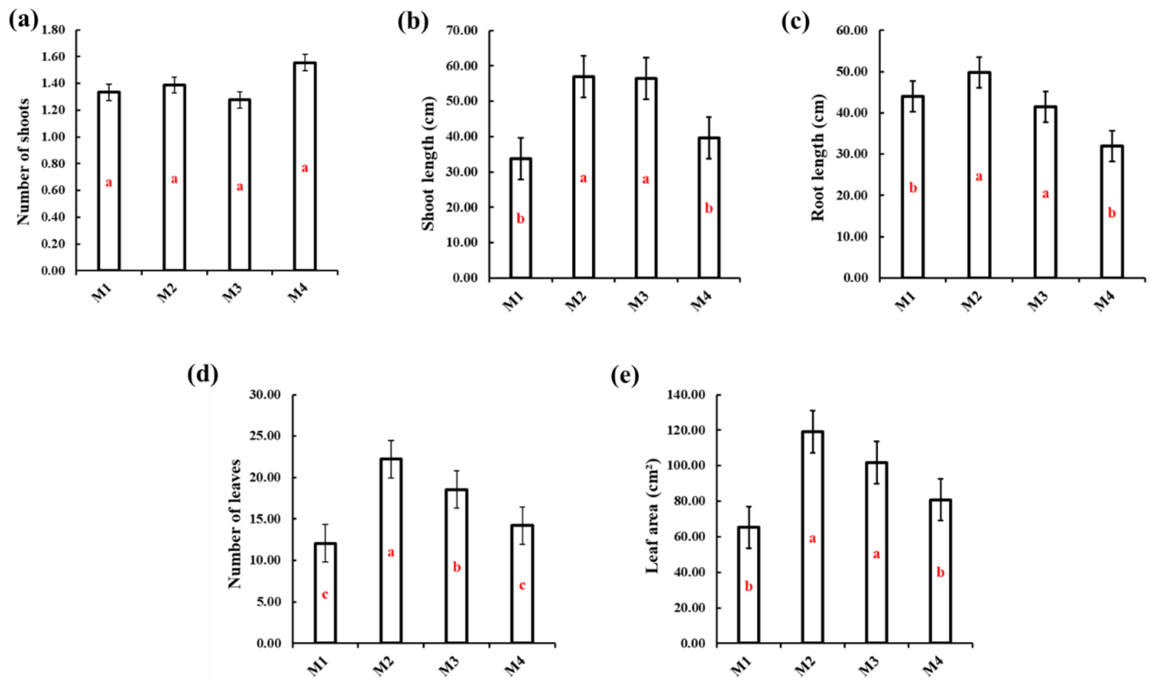

Figure 3. Effect of different planting media compositions on vegetative growth of grapevine stem cuttings, including (a) number of shoots, (b) shoot length, (c) root length, (d) number of leaves, and (e) leaf area. Treatments consisted of M1 = sand + soil (1:1) without manure addition; M2 = sand + soil + cattle manure (1:1:1); M3 = sand + soil + goat manure (1:1:1); and M4 = sand + soil + chicken manure (1:1:1). Bars represent the mean ± standard error. Different letters indicate significant differences according to Duncan's Multiple Range Test at $p \leq 0.05$

A more pronounced response was observed in shoot elongation. Grapevine cuttings grown in the cattle manure-based medium reached a shoot length of 57.0 cm, compared with only 34.0 cm in the control treatment. Similarly, the goat manure treatment produced shoot lengths of 56.5 cm, whereas the chicken manure treatment reached only 40.0 cm. Relative to the control treatment, shoot length increased by 67.6% and 66.2% under cattle and goat manure treatments, respectively. Improved shoot elongation under these treatments was likely associated with enhanced nutrient retention, media aeration, and water availability, which collectively support active cell division and elongation processes during vegetative growth [40]. Organic amendments also improve microbial activity and cation exchange capacity, thereby increasing nutrient uptake efficiency during root establishment [41].

Root development exhibited a similar trend. The cattle manure treatment produced the longest roots (50.0 cm), followed by the goat manure treatment (41.5 cm), whereas the chicken manure treatment produced the shortest roots (32.0 cm). Compared with the control treatment (44.0 cm), root length increased by 13.6% under cattle manure treatment but decreased by 27.3% under chicken manure treatment. Improved root elongation under cattle manure treatment indicates that this medium provided more stable physicochemical conditions for root penetration, oxygen diffusion, and water absorption [42]. Conversely, the relatively poor root performance observed in the chicken manure treatment may indicate rapid nutrient mineralization and temporary osmotic imbalance within the rooting zone under tropical conditions [43]. Under high-temperature environments, rapid organic matter decomposition may accelerate ammonification and salt accumulation, thereby reducing root elongation efficiency and limiting stable assimilate partitioning during early vegetative establishment [44].

Leaf development showed the strongest response to planting media composition. Grapevine cuttings grown in the cattle manure-based medium produced 22.2 leaves plant^{-1}, whereas the control treatment produced only 12.1 leaves plant^{-1}. Goat manure treatment produced 18.7 leaves plant^{-1}, while chicken manure treatment generated 14.3 leaves plant^{-1}. A similar pattern was observed for leaf area, where the cattle manure treatment produced the largest canopy area (119.0 cm^2), followed by goat manure treatment (102.0 cm^2), whereas the control and chicken manure treatments produced only 65.0 and 81.0 cm^2, respectively. Relative to the control treatment, leaf number and leaf area increased by 83.3% and 83.1%, respectively, under cattle manure treatment. Enhanced leaf formation and canopy expansion indicate improved photosynthetic establishment and assimilate production during the nursery stage [45]. Larger canopy structures increase light interception efficiency and carbon assimilation capacity, thereby supporting continuous vegetative growth and biomass accumulation [46].

The better plant growth seen with cattle manure is due to slow nutrient release, steady root conditions, and better canopy growth. These factors helped the grapevine cuttings grow shoots and roots and store nutrients well in tropical lowland areas [47].

3.2. Effect of Planting Media Composition on Biomass Accumulation of Grapevine Stem Cuttings

Plant biomass accumulation was markedly affected by planting media composition (Figure 4). In general, media enriched with cattle and goat manure promoted greater fresh and dry biomass accumulation than the control and chicken manure-based media. This response indicates that organic manure improved nutrient availability, water retention, and root-zone conditions, thereby supporting more efficient vegetative growth and assimilate production during the propagation phase [48].

The highest plant fresh weight was observed in the cattle manure treatment, reaching 37.0 g, followed by the goat manure treatment with 34.0 g. In comparison, the control and chicken manure treatments produced fresh weights of only 26.7 and 26.0 g, respectively. Relative to the control treatment, fresh biomass increased by 38.5% under cattle manure treatment and by 26.9% under goat manure treatment. Increased fresh biomass accumulation under these treatments was closely associated with stronger shoot elongation, larger canopy development, and improved root establishment observed in the previous section. Enhanced vegetative growth increases photosynthetic activity and assimilate translocation, thereby supporting greater biomass production during the nursery stage [49].

A similar trend was observed for plant dry weight. Grapevine cuttings grown in the cattle manure-based medium accumulated the highest dry biomass (26.5 g), followed by the goat manure treatment (23.0 g), where as the control and chicken manure treatments produced only 18.9 and 17.2 g, respectively. Relative to the control treatment, dry biomass increased by 40.4% under cattle manure treatment and by 22.3% under goat manure treatment. Increased dry biomass indicates more efficient carbon assimilation and assimilate partitioning during vegetative establishment [50]. Organic amendments may improve root-zone aeration, microbial activity, and nutrient retention, thereby supporting sustained plant growth and biomass formation under tropical nursery conditions [51].

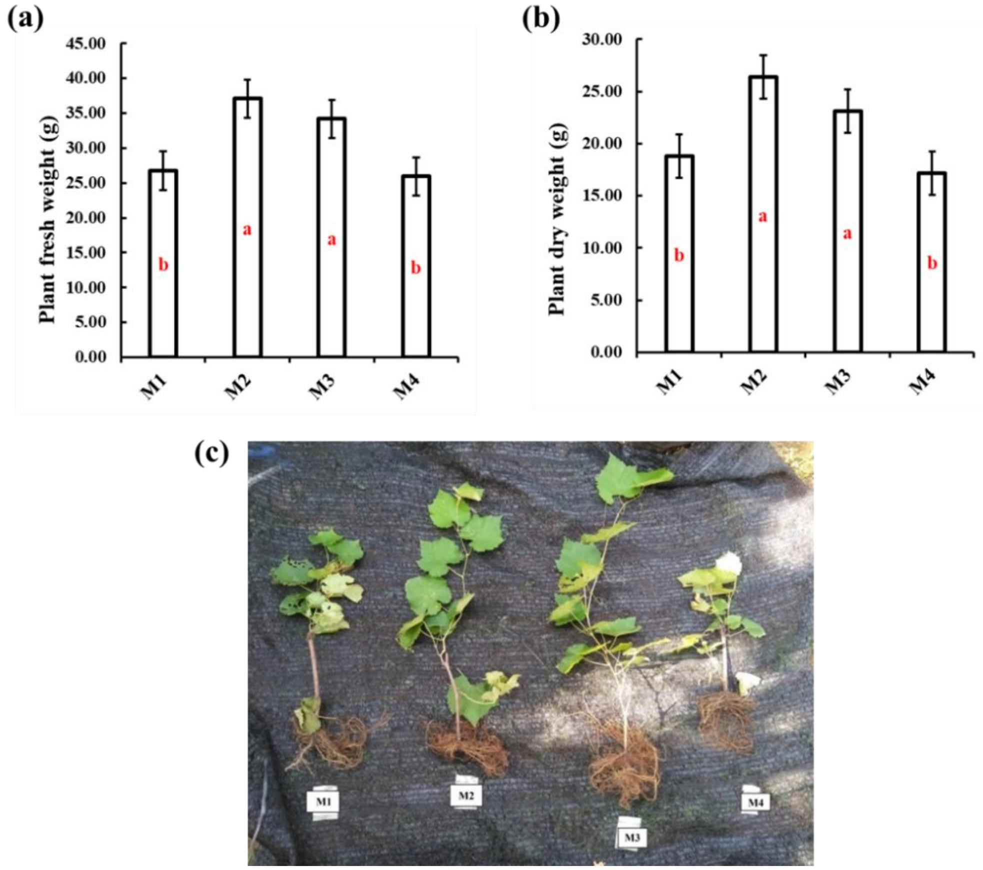

Figure 4. Effect of different planting medium compositions on biomass accumulation of grapevine stem cuttings, including (a) plant fresh weight, (b) plant dry weight, and (c) representative morphology of grapevine stem cuttings grown under different planting media treatments. Treatments consisted of M1 = sand + soil (1:1) without manure addition; M2 = sand + soil + cattle manure (1:1:1); M3 = sand + soil + goat manure (1:1:1); and M4 = sand + soil + chicken manure (1:1:1). Bars represent the mean ± standard error. Different letters indicate significant differences according to Duncan's Multiple Range Test at $p \leq 0.05$.

Interestingly, although the chicken manure treatment stimulated greater shoot emergence, this response was not followed by proportional biomass accumulation. The relatively lower fresh and dry biomass observed under this treatment indicates that rapid nutrient release alone was insufficient to support balanced vegetative growth. Chicken manure generally contains relatively high nitrogen concentrations and rapid nutrient-release characteristics under tropical environmental conditions [52-53]. Too many nutrients can cause temporary stress and an uneven nutrient mix in the root area. This can slow down root growth and reduce how well plants use nutrients. As a result, plants grown with chicken manure may not grow as steadily as those grown with cattle or goat manure [54-55].

The integration of robust root growth, canopy establishment, and biomass accumulation observed under cattle manure treatment underscores the necessity of balanced nutrient mineralization and stable media conditions for enhancing the quality of grapevine cuttings during early plant establishment. These findings emphasize the significance of synchronized root–shoot development, rather than shoot proliferation alone, in determining successful vegetative establishment under tropical conditions [56-57].

3.3. Pearson Correlation Analysis among Vegetative Growth and Biomass Variables

Pearson correlation analysis revealed strong interrelationships among vegetative growth and biomass variables of grapevine stem cuttings (Figure 5). Shoot length exhibited very strong positive correlations with root length (r = 0.95), number of leaves (r = 0.96), plant fresh weight (r = 0.95), and plant dry weight (r = 0.89). These results indicate that shoot elongation was closely associated with improved canopy establishment and biomass accumulation under lowland tropical conditions [58].

Leaf-related variables showed the strongest relationships with biomass production. The number of leaves exhibited strong positive correlations with plant fresh weight (r = 0.96) and plant dry weight (r = 0.94), whereas leaf area also showed strong positive correlations with plant fresh weight (r = 0.94) and plant dry weight (r = 0.91). These findings demonstrate that leaf development plays a central role in biomass formation because increased canopy expansion directly enhances photosynthetic capacity and assimilate accumulation [59]. Larger canopy structures improve light interception efficiency and carbon fixation, thereby supporting continuous vegetative growth during the propagation phase [60]. Plant fresh weight and plant dry weight showed the strongest relationship among all variables (r = 0.99), confirming that increased fresh biomass was followed by actual dry matter accumulation rather than merely increased water content [61]. Root length also exhibited positive correlations with plant fresh weight (r = 0.72) and plant dry weight (r = 0.81), indicating that improved root development enhanced nutrient and water uptake efficiency required for biomass formation [53].

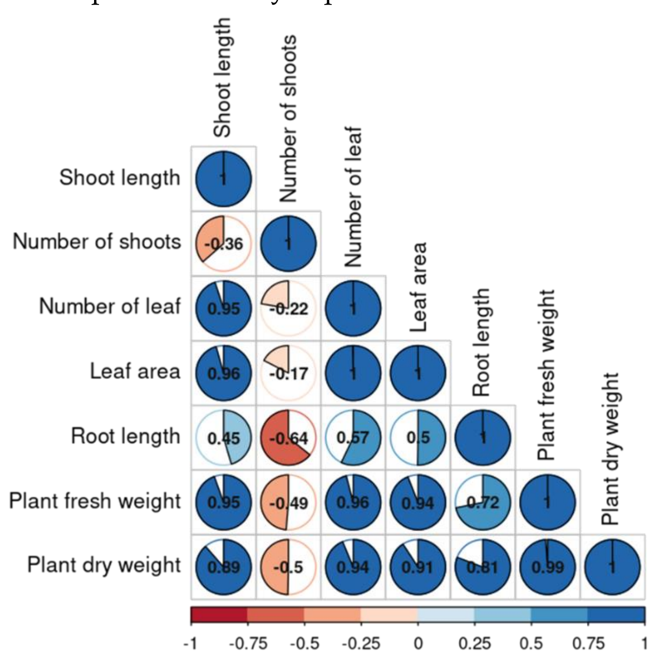

Figure 5. Pearson correlation matrix among vegetative growth and biomass variables of grapevine stem cuttings under different planting medium compositions. Blue and orange circles indicate positive and negative correlations, respectively. The circle size and color intensity represent the strength of the correlation coefficient (r). The variables included the number of shoots, shoot length, root length, number of leaves, leaf area, plant fresh weight, and plant dry weight.

In contrast, the number of shoots showed negative correlations with several vegetative and biomass-related variables, including shoot length (r = −0.36), leaf area (r = −0.64), plant fresh weight (r = −0.49), and plant dry weight (r = −0.50). These findings indicate that shoot proliferation alone does not necessarily reflect seedling vigor. Instead, successful grapevine seedling establishment was more strongly associated with balanced vegetative growth characterized by synchronized root development, canopy expansion, and assimilate accumulation [62]. These results emphasize that integrated root–shoot development is the principal determinant of grapevine cutting quality throughout the nursery period under tropical lowland conditions. These physiological relationships confirm that successful grapevine propagation depends on coordinated root establishment, canopy expansion, and biomass accumulation rather than shoot emergence alone [63] .

4. Conclusion

Planting media composition significantly affected vegetative growth and biomass accumulation of grapevine stem cuttings in tropical lowland nurseries. The sand, soil, and cattle manure (1:1:1) mix yielded the best vegetative performance: shoot lengths of 57.0 cm, 22.2 leaves per plant, leaf area of 119.0 cm^2, fresh weight of 37.0 g, and dry weight of 26.5 g. Compared with the control, the cattle manure medium increased shoot length, leaf number, leaf area, fresh weight, and dry weight by 67.6%, 83.3%, 83.1%, 38.5%, and 40.4%, respectively. In contrast, chicken manure promoted shoot emergence but was less effective for root development and biomass, showing rapid nutrient release alone was insufficient for balanced growth..

Biomass accumulation was strongly linked to canopy establishment, especially leaf number and area, while shoot number had weak and negative correlations with most vegetative and biomass variables. This confirms grapevine seedling establishment relies more on coordinated root–shoot development and assimilate accumulation than shoot proliferation. Incorporating cattle manure into propagation media is an effective, sustainable strategy to enhance nursery-stage propagation efficiency and seedling quality of grapevine in tropical systems. The study also offers practical insights for developing low-cost, environmentally sustainable nursery media technologies for grapevine propagation in tropical conditions.

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