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The Effect of Media Composition on the Growth of Fig (*Ficus carica* L.) Grafts

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Abstract. *The fig plant is cultivated for its fruit due to its high economic value. Vegetative propagation can serve as an alternative for mass propagation of fig plants, such as grafting. Vegetative propagation of figs is conducted in several ways, including grafting and cuttings. The problems encountered in grafting are mainly caused by unsuitable media conditions. This research aims to determine the best composition of grafting media for fig plants. The study was conducted in Dwiwangsa Tin Garden Park, Sidomulyo Village, Krian District, Sidoarjo Regency, East Java. Rainfall at the research site was classified as dry season, with 0 mm in October 2023, 7 mm in November 2023, 150 mm in December 2023, 211 mm in January 2024, and 485 mm in February 2024. The research employed a randomized block design (RBD) consisting of nine media combination treatments. The treatments included soil medium, husk medium, husk charcoal medium, cocopeat medium, sawdust sewing powder medium, a combination of soil and husk medium (1:1), a combination of soil and charcoal husk medium (1:1), a combination of soil and cocopeat medium (1:1), and a combination of soil and sawdust medium (1:1). Each grafting medium showed a different growth response in terms of root number. Based on the results, the husk charcoal medium produced the highest values, with 89.8 roots, root length of 7.24 cm, root diameter of 1.38 cm, root fresh weight of 5.22 g, root volume of 7.7 ml, and root dry weight of 0.37 g.*
Keywords: *Fig; graft media; grafts; roots.*

Type of the Paper: Regular Article.

1. Introduction

The fig plant (*Ficus carica* L.) originates from the Middle East, later spreading to the Mediterranean mainland and eventually worldwide [1]. It has considerable social and economic importance [2]. The fig tree is widely cultivated for its sweet, juicy fruit and soft, edible bark [3]. *Ficus carisca* is an economically important horticultural plant due to its abundant secondary metabolites [4]. Fig fruit offers various health benefits and has applications in pharmaceutical industry [5]. Fig by-products are also an important source of structurally diverse bioactive molecules with antidiabetic, anti-inflammatory, antitumor, immunomodulatory, and cardioprotective properties [6]. This plant has great potential for further development and

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cultivation, and its high economic value can contribute to foreign exchange earnings through increased production.

Fig propagation can be conducted through vegetative and sexual methods [7]. Generative propagation occurs through pollination facilitated by the wasp *Blostophaga psenes* L., which lives in Central Asia and Mediterranean [8]. However, sexual propagation is less preferred due to low seed viability [9]. Consequently, vegetative propagation serves as an alternative for mass propagation of fig plants [10]. Vegetative propagation of figs is conducted through several methods, including grafting and cuttings, with grafting being the most commonly used by farmers [11]. Other vegetative propagation methods, such as grafting, face challenges including incompatibility between the shoot and the rootstock [12]. Grafting suitability refers to the successful healing between the rootstock and scion, along with the normal functioning of both tissues [13]. This technique holds great potential for improving cultivation efficiency [14].

Grafting is one of the vegetative propagation methods. It is a technique in which branches of the parent tree are wounded or cut and then wrapped in planting media to stimulate root formation. This technique has long been practiced by farmers. In grafting, roots develop while the grafted branch remains attached to the parent tree [15]. The main problem in this technique is caused by unsuitable media conditions. An optimal root system requires appropriate grafting media. Several media-related factors contribute to inefficiency, such as insufficient nutrient content for root growth, limited availability, low porosity, etc [16].

The use of appropriate planting media can support successful grafting both physically, chemically, and biologically, allowing the plant to grow well and adapt to external conditions [17]. The grafting medium plays a crucial role in inducing root growth. A medium with good porosity produces a strong root system, while nutrient-rich and fertile media promote healthy root development. The proper type of grafting medium ensures optimal grafting success. The composition of the substrate is crucial for the growth of grafted seedlings. Several methods combine various media materials to prepare the best media for graft growth. The ideal substrate is well-drained soil enriched with organic matter [18]. A combination of soil, manure, and vermicompost significantly affects grafted mango plants [19]. Similarly, media mixtures containing cocopeat, leaf fertilizer, and compost are considered ideal for cultivating mango grafts [20]. Organic waste material such as husks, husk charcoal, cocopeat, and sawdust are also used as grafting media [21]. Each medium exhibits different properties in terms of moisture, aeration of the grafting media, and nutrient content [22]. This study aims to determine the optimal composition of grafting media for root growth in fig plants (*Ficus carica L.*), thereby supporting increased fig production through the availability of uniform superior seedlings..

2. Materials and Methods

The research was conducted from October 2023 to February 2024 at Dwiwangsa Tin Garden Park, Sidomulyo Village, Krian District, Sidoarjo Regency, East Java. During the study, rainfall at the site was classified as the dry season, with 0 mm in October 2023, 7 mm in November 2023, 150 mm in December 2023, 211 mm in January 2024, and 485 mm in February 2024. The research employed a randomized block design (RBD) consisting of nine grafting media treatments, each with five replications. The treatments were: P1 (soil media), P2 (husk media), P3 (husk charcoal media), P4 (cocopeat media), P5 (sawdust media), P6 (soil + husk, 1:1), P7 (soil + husk charcoal, 1:1), P8 (soil + cocopeat, 1:1), and P9 (soil + sawdust, 1:1). The soil used was alluvial.

The study started by selecting branches of the mother plant with diameters of approximately 10-15 mm and dense leaves. Each mother plant was only grafted once, requiring approximately 45 mother plants. All mother plants were placed in the same location, with uniform sunlight exposure and cultivation method. A circular incision about 1 cm wide was made on the stem, approximately 25 cm from the shoot. The trunk was peeled to remove the bark and sap. The stem was left to dry for 2-3 days before being wrapped with the grafting medium. Maintenance included watering and keeping the planting medium moist. Graft cutting was conducted after 28 days, after which the grafts were planted in polybags [23].

The observed variables included root number, root length, root diameter, fresh root weight, root volume, and dry root weight. Root number was determined by counting the emerged roots, root length was measured with a ruler, root diameter with a caliper, fresh and dry weights with a digital scale, and root volume with a beaker glass. The data were analyzed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (α= 0.05). Data analysis was conducted using SPSS version 26.

3. Results and Discussion

A suitable rooting medium for transplantation should provide adequate drainage, aeration, and nutrient content to support the growth and development of transplant roots. Each grafting medium produced a different growth response in terms of root number. Data analysis showed that grafting media had a significant effect on graft growth across all parameters, including root number, root length, root diameter, fresh root weight, root volume, and dry root weight. All observed parameters showed significance values of less than 0.005 (sig. < 0.005) (Table 1).

The result showed that husk charcoal medium produced the highest number of roots (Fig. 1). Its porous structure and high carbon content create an ideal environment for root growth [24]. The porous conditions provide space for root growth, while the charcoal's ability to absorb sunlight, improve aeration, and enhance water retention collectively stimulate root respiration and increase overall root vigor [25].

Table 1. Recapitulation of data analysis results

Parameter	F value	Sig.
Number of roots	24.940	.000
Root length	30.463	.000
Root diameter	11.897	.000
Fresh root weight	37.208	.000
Root volume	28.767	.000
Dry root weight	64.632	.000

Based on the results (Fig. 1), the husk charcoal medium (P3) produced the highest number of roots (89.8), which was significantly different from the other treatments except husk medium (P2). The soil and cocopeat medium (P8) produced the lowest number of roots (40.8). This was attributed to soil porosity and water infiltration, as soil has lower porosity than husk charcoal but higher water-holding capacity than all other media.

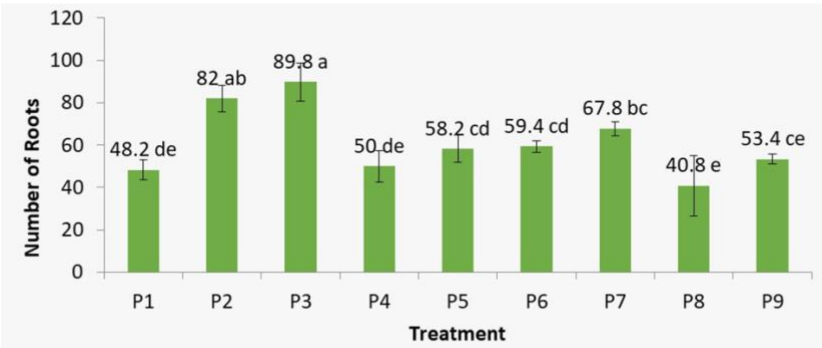

Fig. 1. Number of roots of fig graft roots

The soil media (P1) produced 48.2 roots, likely due to its dense structure, which inhibited optimal root growth. The husk medium (P2) produced 82 roots, attributed to its light structure that facilitated root formation within the media pores. The husk charcoal medium (P3) showed the highest and most significant result, producing 89.8 roots. This was due to its light structure and dark color, which optimize sunlight absorption, along with its complex nutrient content. The cocopeat medium (P4) produced 50 roots. Its high water-holding capacity created excessive moisture, which hindered root development. This result was not as high as that of the sawdust medium (P5), which produced 58.2 roots.

The combined media treatments produced varying numbers of roots. The soil–husk medium (P6) yielded 59.4 roots, the soil and charcoal husk medium (P7) yielded 67.8 roots, the soil and cocopeat medium (P8) yielded 40.8 roots, and the soil and sawdust medium (P9) yielded 53.4 roots. Among these, the soil and husks medium (P7) produced the highest roots number (67.8). This result is likely due to the dense soil structure being balanced by the lighter husk charcoal, which facilitated better root penetration and development compared with the other combination treatments.

The combination of soil and cocopeat reduces media porosity, thereby limiting optimal root elongation and exploration [26]. Cocopeat has a maximum porosity of 61.57% and water-holding capacity about 66.37%. Soil pores play a major role in regulating water movement in the soil and affect the soil's ability to retain water. The benefit of cocopeat as a planting medium lies in its strong water-binding ability, as it can store water while also providing important nutrients such as sodium (N) and phosphorus (P) [27].

Treatment with husk charcoal media (P3) produced more roots, although not significantly different from husk media (P2). However, husk media (P2) resulted in longer roots compared to husk charcoal media (P3) (Fig. 2). Husk charcoal media (P3) produced an average root length of 7.24 cm, while husk media (P2) produced 8.12 cm. This phenomenon is related to differences in porosity between husk and husk charcoal. Husk charcoal has a porosity of 44 to 70 % [28], while husk exhibits a similar porosity, around 68.94%, and, under optimal conditions, can reach 72.21 to 85.28 % [29]. The key difference between husk and husk charcoal lies in their retain water capacity [30]. Husk, with its smaller pore size and higher water-holding capacity, provides a more favorable environment for root elongation and exploration.

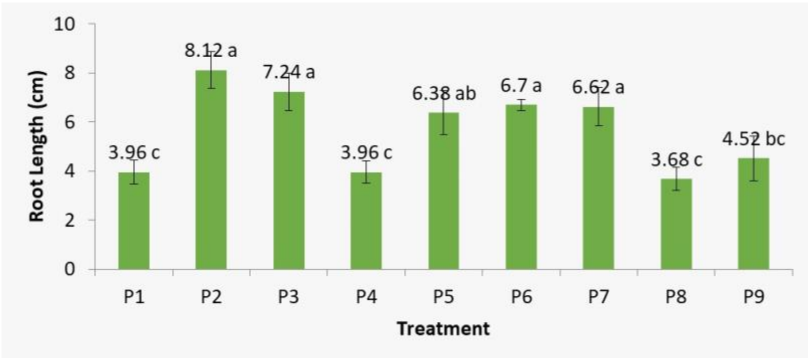

Fig. 2. Root length of fig grafts

In Fig. 2, the best treatment was husk media (P2), with an average root length of 8.12 cm compared to husk charcoal media (P3) at 7.24 cm, although the difference was not statistically significant. It is due to the root length that reflects the plants' ability to anchor in the medium, where longer roots enhance nutrients absorption. This ability is influenced by the medium's porosity and nutrient availability [31]. The shortest root length was observed in soil and cocopeat media (P8), measuring 3.68 cm.

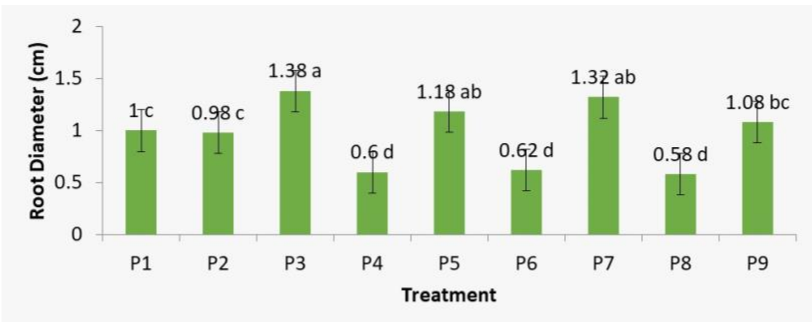

Fig. 3. Root diameter of fig graft

The result of root diameter presented in Fig. 3 shows that husk charcoal media (P3) produced the largest root diameter, 1.38 cm, which was significantly different from the other treatments. This is due to the characteristic of roots, which are determined by environmental factors and genotype. Root tissues exhibit flexibility, enabling adaptation to the shape of the growth medium. Roots can grow in soilless media such as rockwool and organic media such as luke cocopeat and husk charcoal. Several crucial factors affecting root growth include the medium's water- and nutrient-binding capacity, high porosity, and low strength of the media [32].

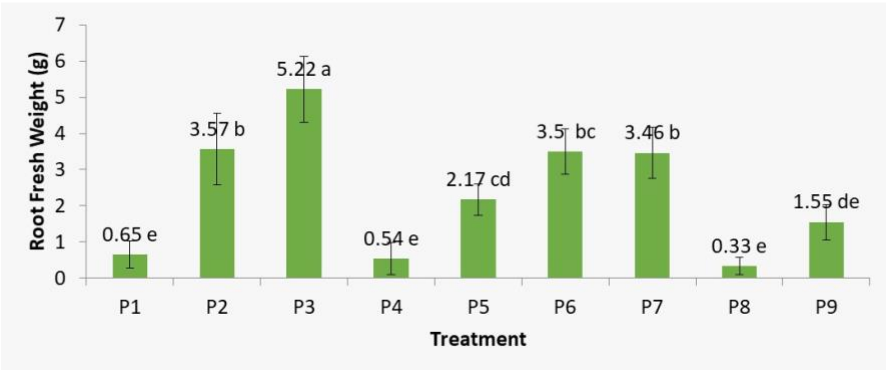

Fig. 4. Fresh weight of fig graft roots

Treatment with husk charcoal media (P3) produced the highest fresh weight, with an average of 5.22, compared to the other treatments. This is caused by the ability of husk charcoal, which has good water retention and organic-based content. Husk charcoal contains approximately 31% K2O, 15% P2O5, 0,3% N, along with other essential and non-essential nutrients. It also possesses high cation exchange capacity and effectively absorbs sunlight [33]. The ability of roots to absorb water and nutrients is reflected in their fresh weight. Measuring the fresh weight of roots indicates root water content, which is essential for root development. Treatment with husk charcoal media (P3) was the most effective for root fresh weight, as shown in Fig. 4. Fresh root weight shows the plant's roots production capacity to absorb water and nutrients from the growth media. It also serves as a quantitative indicator of plant growth, representing increases in biomass. This parameter is particularly useful for monitoring dynamic growth processes during cellular expansion and division [34].

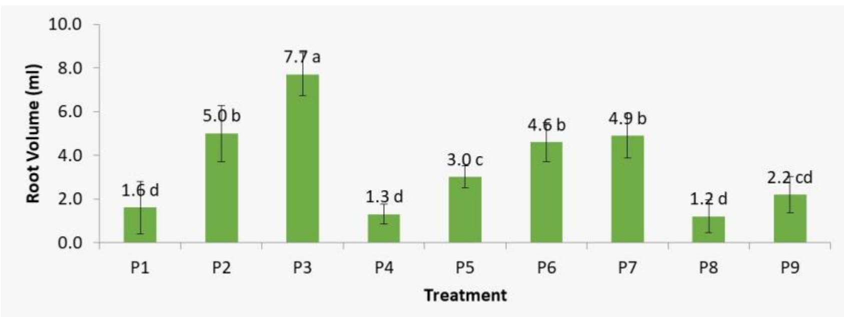

Fig. 5. Root volume of fig graft

Root volume in each treatment showed significant differences. Root volume is related to greater root mass and weight. Optimal grafting media can enhance root growth, resulting in larger root volume. Good media porosity provides sufficient space for root expansion, thereby increasing root size.

Fig. 5 shows that the husk charcoal media (P3) produced a value of 7.7, while the average of the other eight treatments ranged from 1.2 to 5.0. This development was attributed to the sufficient availability of nutrients in the treatment media. Root growth and development are determined by the structure of the growing medium. Under optimal conditions, husk charcoal enhances the plant's ability to absorb nutrients at maximum capacity. Moreover, the application of husk charcoal provides an additional nitrogen supply [33], thereby maintaining optimal plant growth and enhancing root proliferation [35]. A well-developed root system is essential for plant vigor, as roots are primarily responsible for absorbing water and minerals from the soil and transporting them for metabolic utilization [36].

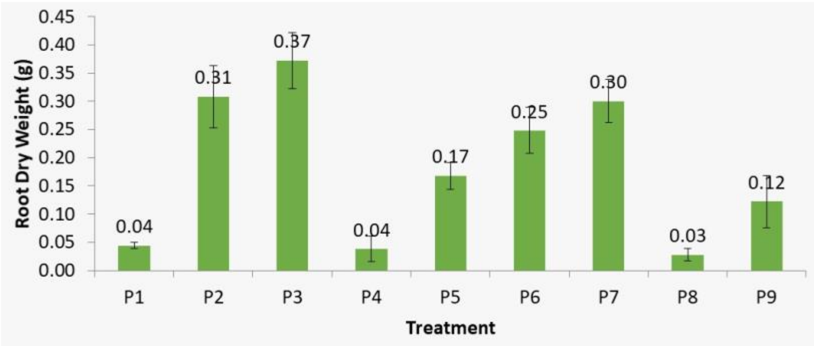

Fig. 6. Dry weight of fig graft roots

The dry mass of roots is strongly correlated with root volume and density, with larger root systems producing greater dry mass. Plant growth is predominantly driven by photosynthesis, which contributes to at least 90% of plant dry matter. Biomass serves as a practical indicator of a plant's photosynthetic productivity. As shown in Fig. 6, the best treatment was P3 with husk charcoal media, yielding an average dry mass of 0.37.

Fig. 7. Growth of shoots and roots from graft media treatment after 1 month.

Treatment of husk charcoal media (P3) showed a significantly greater effect compared to the other eight treatments. This increase can be attributed to the nutrient content of rice husk charcoal, particularly nitrogen, phosphorus, and potassium. Potassium plays an important role in plant metabolism, energy generation, and root development. An extensive root system enhances nutrient acquisition, thereby promoting strong plant growth.

The development of the root system is a crucial parameter in determining the success of vegetative propagation. Successful rooting requires appropriate plant physiological status and optimal environmental conditions to support the rhizogenesis process, as shown in Fig. 7.

As illustrated in Fig. 7, adventitious roots develop from the wounded cutting surface. This phenomenon is attributed to the localized accumulation of auxin signaling molecules at the wound site, which subsequently initiates root formation. Auxin signaling exerts distinct roles within individual cell types during during Arabidopsis. Specifically, auxin activity in the cambium is crucial for tissue adhesion and vascular connection, as it promotes both cell division and expansion within the graft union zone [37].

4. Conclusions

Based on the research findings, husk charcoal media (P3) was identified as the most effective medium for fig grafting. This treatment (P3) produced significantly superior root growth, with 89.8, a root length of 7.24 cm, a root diameter of 1.38 cm, a root fresh weight of 5.22 g, a root volume of 7.7 ml, and a root dry weight of 0.37 g.

Abbreviations

Not applicable.

Data Availability Statement

Data will be made available on request.

CRediT Authorship Contribution Statement

Didik Pudji Restanto: Conceptualization, data curation and Writing-Original Draft Preparation. **Moh Nuri Antono:** Formal analysis and funding acquisition. **Setiyono:** Investigation and supervision. **Wildan Muhlison:** Investigation and supervision. **Mohammad Candra Prayoga:** Validation, visualization, writing original draft, Writing review and editing. **Fauziatuz Zahro:** Methodology, project administration, resources, and software.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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