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Kenaf-Based Composite Posts as Alternative Supports for Black Pepper (*Piper nigrum* L.)

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ABSTRACT

Black pepper is a perennial climber and the provision of a supporting post is important for the successful establishment of black pepper planting in the producing countries. With the high cost of establishing black pepper planting using the traditional Belian post, there is a need to develop alternative posts for its sustainability. The study was carried out to evaluate the use of Kenaf composite posts for black pepper planting compared to the commonly used Belian post as supporting material. Three types of Kenaf composite posts, namely, Kenaf Extrusion, Kenaf Pultrusion and Kenafkrete posts, together with mechanically controlled fibre-glass posts, were investigated for black pepper planting. The epiphytical response of black pepper plant, accelerated laboratory decay test, leaf temperature, leaf-to-air vapour pressure deficit and the leaf gas exchange rate were the parameters assessed in this study to indicate the suitability of the composite post for black pepper growing. The trial plot was established at thoroughly exposed conditions to determine the sustainability of Kenaf composite posts at open field conditions. The study demonstrated that adventitious roots of black pepper plants were able to bind on all types of support except the Kenafkrete post, which showed a low number of cling roots. On durability observation, the Kenaf Extrusion post showed severe bending and was intolerant to field weather conditions, whereas the Kenafkrete post showed moderate level of cracks on the post. The laboratory decay test indicated that Kenaf composite posts were highly resistant to wood decay fungi

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and performed better than Belian post. It was discovered that Kenaf Extrusion contributed to an adverse microclimate environment for the growth of black pepper by showing significantly ($p<0.05$) higher leaf temperature and leaf-to-air VPD. Leaf photosynthesis rates (*A*) and leaf stomatal conductance (*gs*) of black pepper supported by Belian, Kenaf Pultrusion, Kenafkrete and fibre-glass were comparatively ($p<0.05$) higher than recorded for Kenaf Extrusion. The results of this study implied that among the supports studied, Kenaf Pultrusion and fibre-glass posts showed positive results as good alternative supports to the currently used Belian post for black pepper planting.

Keywords: Black pepper (*Piper nigrum* L.), Kenaf (*Hibiscus cannabinus* L.), supporting post, composite post

INTRODUCTION

Black pepper (*Piper nigrum* L.) is the most important spice traded internationally and it is cultivated in many tropical regions of the world like India, Brazil, Vietnam, Indonesia, Malaysia and Sri Lanka. As black pepper is a climber, it requires physical post support for proper growth, development and yield. Providing ideal support is important for successful establishment of black pepper holdings. Both deadwood support and living support can be used for black pepper cultivation. In Malaysia and parts of Indonesia, the preferred support material is the wooden pole of the Belian tree (*Eusideroxylon zwageri* Teijsm. & Binn.), also known as Borneo Ironwood, which is high density, heavy and construction-timber resistant to termite attack (Dinesh et al., 2005). The Ironwood poles are durable, lasting for more than 20 years, well beyond the lifespan of pepper plants (Paulus et al., 2011). However, Belian posts are expensive and their acquisition would be the most expensive item in the establishment of a farm. Other hardwood such as Selangan Batu (*Shorea* sp.) and semi-hardwood, mainly Somah (*Ploiarium alternifolium* [Vahl] Melchior) have been used by farmers. Most of them do not last beyond five years after planting. Therefore, farmers sink a new post to reinforce the original post when the latter is at the initial stage of rotting.

As an alternative to Belian posts, farmers have been using living supports for pepper cultivation. In 1992, MARDI had introduced Dedap (*Erythrina indica*) as an alternative live support system for pepper cultivation in Johor for its low establishment cost (Abd. Rahman Azmil & Yau, 1992). However, it was found that the living supports were severely infested by the insect pest, Erythrina gall wasp (*Quadrastichus erythrinae* Kim) (Paulus & Megir, 2006) and therefore, no longer recommended for black pepper planting. Currently in Sarawak, two living supports, Gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp) and Simpuh (*Dillenia suffruticosa* [Griff ex Hook. F. & Thomson] Martelli) are commonly used for the planting of black pepper (Paulus & Megir, 2006). For Gliricidia, a terminal shoot arising from the upper portion of the stake has to be pruned regularly to maintain a height for black pepper growing, and this task is labour intensive. As for Simpuh, the post can only be obtained from trees found in young secondary forests in Sarawak.

With the high cost of deadwood support and unavailable ideal living support, there is a need to develop alternative posts for black pepper planting. Other hardwood and semi-hardwood timber species have been tried as substitutes for Belian, but most of them were found to be unsatisfactory due to lack of durability. The use of cement posts in pepper planting has been practised in most farms in Peninsular Malaysia with satisfactory outcome. However, growth performance at the early stage has been reported to be less promising. Researchers revealed that the burning surfaces of cement posts once exposed to sunshine may discourage attachment and growing of adventitious roots on the post. The nature of this climber shows more preferable cling on hardwood species like *Eusideroxylon zwageri*, probably due to less desiccated surfaces compared to cement posts. Therefore, the key success of developing a viable post for pepper planting is the durability of the post and at the same time, the post surfaces must be desirable for the pepper root to cling on.

Kenaf fibre composite presents as a potential material to develop as an alternative post for black pepper planting support with its good mechanical strength. Previous studies have shown that Kenaf fibre composite has properties superior to unreinforced matrices such as polypropylene, which has poor impact strength (Rowell et al., 1999; Anuar et al., 2008). Other studies also showed that natural fibres such as Kenaf have been used with biodegradable polymer as fibre reinforced biocomposites due to their good mechanical properties, lower cost and light weight (Yussuf et al., 2010). In the field of technical utilisation of natural fibres, Kenaf reinforced composites are one of the most important areas for further exploration (Huda et al., 2008). Therefore, Kenaf fibre composites incorporated with long lasting binders like PVC, cement and fibre-glass are potential solutions in developing the ideal post for black pepper growing.

The objective of this study was to evaluate the effect of different types of alternative Kenaf composite posts for the sustainable growth of the black pepper plant. The aim was to examine field performance including epiphytical response of adventitious roots, black pepper's photosynthetic rate, stomatal conductance rate, leaf vapour pressure deficit (VPD) and leaf temperature and to run laboratory tests to determine the appropriateness of Kenaf-based composite as an alternative to currently recommended posts in black pepper cultivation. This is the first report on using Kenaf composite posts as an alternative support for black pepper cultivation in Malaysia.

MATERIALS AND METHOD

Plant Materials

In this study, the observation plot was established at Serikin Farm, Bau, Sarawak (East Malaysia) in September 2014. The black-pepper cuttings of the variety Semongok Aman were obtained from the nursery of Serikin farm. The black-pepper cuttings were placed in rooting beds covered with river sand to the level of the fourth node of a five-node cutting. Watering of cuttings was done manually once a day. After five weeks, the rooted cuttings were transplanted to the observation plots.

Kenaf Composite Materials

Kenaf-based composite and fibre-glass posts were provided by the National Kenaf and Tobacco Board and certified by SIRIM. Three types of Kenaf-based composite posts were used in this study, Kenaf Extrusion (60% Kenaf fibre, 40% PVC), Kenaf Pultrusion (80% glass fibre yarn, 10% glass fibre mat, 10% Kenaf yarn) and Kenafkrete (10% Kenaf, 30% pilling rode, 60% cement). The fibre-glass post that was composited with synthetic fibres was used as a comparison for mechanical strength with the natural-fibre Kenaf composite post. Belian (Ironwood) was used as a control for examining plant growth of the black pepper.

Experimental Design

The experimental design for this study was a completely randomised design (CRD) with five types of different support poles as treatment. The treatments were: (i) Control – black pepper vines supported on Belian posts, (ii) Kenaf Extrusion – black pepper vines supported on Kenaf-based composite extrusion posts, (iii) Kenaf Pultrusion – black pepper vines supported on Kenaf-based composite pultrusion posts, (iv) Kenafcrete – black pepper vines supported on Kenaf-based concrete posts, and; (v) Fibre-glass – black pepper vines supported on fibreglass posts. Each treatment had five replicates, with each replicate represented by one pole.

The Epiphytical Response of Adventitious Roots of Black Pepper Plant

The percentage of support cling roots was determined in this study by counting the number of posts with cling roots.

$$\text{Support cling roots} = \frac{\text{number of posts with positive cling roots}}{\text{number of posts tested}} \times 100\%$$

Sustainability of Kenaf Composite Posts

A trial plot was established at thoroughly exposed conditions to determine the response of composite posts under open-weather conditions. The sustainability of Kenaf composite posts was evaluated based on the physical observation of the posts.

The Accelerated Laboratory Decay Test

The accelerated laboratory decay test was employed using the agar block culture method, a modified harmonised procedure adopted from Tan et al. (2010). Composite samples and Belian samples were processed to test specimen size as indicated in Table 1. White rot fungus *Coriolus versicolour* (L. ex. Fr.) and brown rot fungus *Gloeophylum trabeum* (Pers. Ex. Fr.) were used in the test. Test specimens were exposed to healthy cultured fungus in agar-based media in culture bottles and subjected to a 16-week trial before being assessed for their weight loss based on the difference in oven-dry weight between before and after fungus exposure, and expressed in percentage. In this study, the decay test on Kenafkrete was omitted due to the required test specimen size as stipulated in the testing standards.

Leaf Temperature and Leaf-to-Air Vapour Pressure Deficit (VPD) Measurement

Using the method employed by Day (2000), leaf temperature and VPD were computed by calculation based on air temperature. It was measured by a fine wire thermocouple using a LICOR LI-6400 XT infrared gas analyser (IRGA) (Lincoln, Nebraska, USA).

Measurement of Gas Exchange of *Piper nigrum*

Gas exchange measurement was determined according to the method by DiCristina and Germino (2006). It was carried out on young fully expanded leaves with the same orientation and layer in the vine crown (middle bottom). Measurements of net photosynthesis on an area basis (*A*) (µmol CO_2 $m^{-2}s^{-1}$) and leaf stomatal conductance (*gs*) (mol H_2O $m^{-2}s^{-1}$) of 25 different leaves per treatment were monitored using a LICOR LI-6400 XT infrared gas analyser (IRGA) (Lincoln, Nebraska, USA). Light intensity (Photosynthetically active radiation, PAR) within the sampling chamber was set to PAR at 900 µmol $m^{-2}s^{-1}$, which was presumed to be the intensity at which photosynthetic rates for black pepper would be maximal (Mathai, 1983; Vijayakumar et al., 1984). The CO_2 flow into the chamber was maintained at a concentration of 400 µmol mol^{-1}. The humidity flow into the chamber was fixed at 500 µmol s^{-1}. Measurement was done on gas exchange parameters at between 1100 and 1200 h.

Data Analysis

One-way Analysis of Variance (ANOVA) at p=0.05 was carried out to determine differences of effects among different types of post. If then required, means separation was analysed using Duncan's Multiple Range Test (DMRT) (Duncan, 1955) at p=0.05 level. All statistical analyses were performed using IBM SPSS statistics 21 (IBM Corp, 2012).

Table 1
Test specimen size and number of replicates per fungus for each type of post

Type of Post	Test Specimen Size (mm)	No. of Replicates per Fungus
Belian	20 x 20 x 6	10
Fibre-glass	22 x 25 x 2	10
Kenaf Extrusion	25 x 25 x 5	10
Kenaf Pultrusion	25 x 25 x 3	10

RESULTS AND DISCUSSION

Plant Growth and the Epiphytical Response of Adventitious Roots of Black Pepper Plant on Kenaf Composite Posts

Table 2 shows the results of the ANOVA analysis and Duncan's mean separation tests for black pepper plant growth and adventitious root response on Kenaf composite posts. There were significant differences ($p<0.05$) in the number of leaves and number of lateral branches among the plants trained on different types of support. The results of the present work showed that plants on Belian post and fibre-glass post grew vigorously, with both supports recording the highest number of leaves. Kenafkrete recorded the lowest growth of black pepper plant compared to the Kenaf Extrusion post and Kenaf Pultrusion post. Since the black pepper plant is a climber, the attachment of adventitious roots on the support posts is essential. This study demonstrated that the adventitious roots of black pepper plants were capable of binding on different types of support (Figure 1A-E). From observation, Kenaf Extrusion, the Pultrusion posts and the Fibre-glass posts had similar binding strength for black pepper adventitious roots (Table 2). Although fibre-glass is a synthetic fibre with no organic materials, the response of black pepper growth and attachment of adventitious roots had no significant difference compared to when the Belian post was used. Kenafkrete showed low inclination for black pepper plant attachment as the concrete post got heated up in the daytime, resulting in drying of clinging roots. The binding feature of adventitious roots is important for enhancing the growth of young shoots upward and allowing them to continue to grow to form black pepper plant canopies.

Sustainability of Kenaf Composite Posts

In this study, the sustainability of Kenaf composite posts was evaluated against the field condition. From observation, the Kenaf Extrusion posts showed significant bending and cracking on the post after eight months' exposure in the open field (Figure 1F). It is believed this was due to the high percentage of PVC composition in the Kenaf Extrusion post with low heat stability under field weather conditions. Kenafkrete is also not recommended for black pepper planting as the post tends to crack easily after long periods of planting. However, it is interesting that fibre-glass was found to be suitable for growing black pepper plants. The fibre-glass posts and Kenaf Pultrusion posts that incorporated fibre-glass performed well in field conditions, causing the black pepper plants to grow vigorously on the posts. The present study also implied that the Kenaf composite posts and fibre-glass did not harbour pests and diseases that could hinder the growth of black pepper plants.

Table 2
Plant growth and response of adventitious roots of black pepper plants on kenaf composite posts

Support	No. of Leaves/Plant	No. of Lateral Branches/Plant	Support Cling Roots (%)
Belian	9.6 ± 1.52^{a}	3.4 ± 2.70^{b}	100
Kenaf Extrusion	5.6 ± 2.30^{ab}	5.6 ± 2.30^{ab}	60
Kenaf Pultrusion	7.6 ± 5.27^{ab}	7.6 ± 5.27^{ab}	60
Kenafkrete	2.8 ± 2.77^{b}	5.0 ± 3.16^{ab}	40
Fibre-glass	9.2 ± 4.44^{a}	9.2 ± 4.4^{a}	60
ANOVA (F value) _Support	3.140*	3.620*	-

* indicates significant at p=0.05. Means followed by the same letter within a column are not significantly different by DMRT at p=0.05. The percentage of support cling roots is only based on the positive response observation; no statistical analysis was done. Mean ± standard error

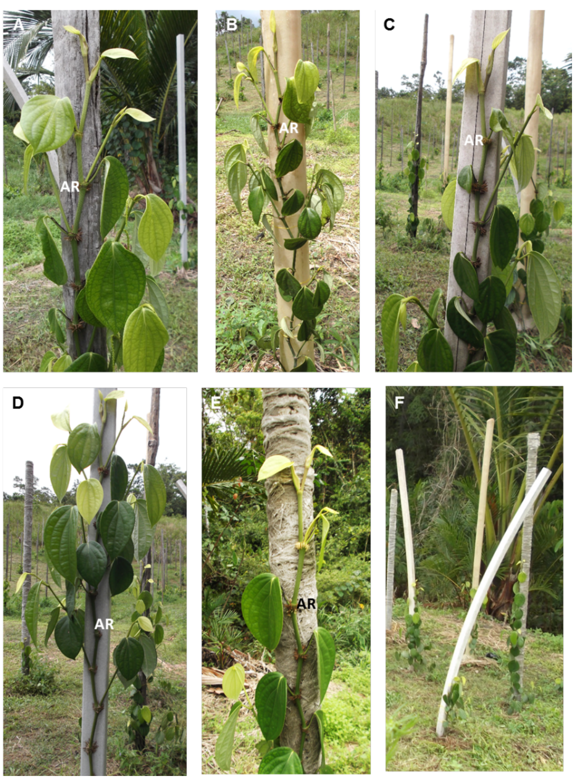

Figure 1. Plant growth and attachment of adventitious roots of black pepper plant on different supports. (A) Belian. (B) Fibre-glass (C) Kenaf Extrusion (D) Kenaf Pultrusion (E) Kenafkrete (F) Bending of the Kenaf Extrusion posts after eight months of planting. AR, Adventitious Roots

The Accelerated Laboratory Decay Test

In this study, the accelerated laboratory decay test focused on durability of the posts against white rot fungi (*Coriolus versicolour*) and brown rot fungi (*Gloeophyllum trabeum*). These fungi are known for their highwood degradation capacity and therefore, were used as an efficient fungus reference for wood degradation in standard tests (Kerem et al., 1999; van Acker et al., 1999; Zabel et al., 1992). Table 3 presents the results of the analysis of the average weight loss of the support posts (Belian, fibre-glass, Kenaf Extrusion and Kenaf Pultrusion) after 16 weeks of exposure to *C. versicolour* and *G. trabeum*. The average weight loss using Belian was the highest, 3.85% and 3.23% in *C. versicolour* and *G. trabeum*, respectively. The Kenaf composite produced through pultrusion method recorded the lowest average weight loss, with 0.03% in *C. versicolour*. However, there was slight increase of weight in Kenaf pultrusion treated with *G. trabeum* (-0.01%), which was due to the variation among the replicates tested. This was followed by the fibre-glass posts, with average weight losses of 0.3% in *C. versicolour* and 0.31% in *G. trabeum*. The Kenaf-composite posts produced through Extrusion method recorded 0.98% average weight loss in *C. versicolour* and 0.08% in *G. trabeum*. In general, the percentage of average weight loss in Belian was significantly higher than when the fibre-glass and Kenaf composite posts were used. According to the standard, an average weight loss of 0%-10% is considered to be highly resistant and weight loss higher than 45% is considered to be slightly resistant or non-resistant (Kartal & Avrilmis, 2005). Thus, all the sample posts tested in this study fell in the category of highly resistant against both white rot and brown rot fungi. The moisture content after exposure to the fungi in the Belian post was also significantly higher compared to the that in the rest of the samples, with 62.62% in *C. versicolour* and 43.44% in *G. trabeum*. The fibre-glass and Kenaf Pultrusion posts showed moisture content in the range of 1.8%-2% and Kenaf Extrusion recorded moisture content in the range of 11%-13%. The high resistance against these two aggressive fungi by fibre-glass and Kenaf composite posts might have been due to the composition of the posts. Fibre-glass is a synthetic fibre consisting of numerous extremely fine fibres of glass that are not affected by the cellulases and lignin-degrading enzymes produced by the decaying fungi (Aziz & Ansell, 2004; Tanaka et al., 1999). The Kenaf Pultrusion composite was more resistant to fungus decay compared to the Kenaf Extrusion composite because Kenaf Pultrusion consisted mainly of fibre-glass compared to the Kenaf Extrusion with its higher percentage of Kenaf fibre. Evidently proved in this study, the Kenaf composite posts were highly resistant against the wood decay fungi and performed better than Belian, which had higher weight loss albeit being in the same resistance class.

Table 3
Mean weight loss % of materials exposed to white rot fungi (Coriolus Versicolour) and brown rot fungi (Gloeophyllum Trabeum) in 16-week trial test

Test Fungi	Post Materials	Weight Loss %	Initial MC* %	MC* % After Exposure	Resistance Classification
C. versicolour	Belian	3.85 ± 0.53[a]	7.97 ± 0.12[a]	62.62 ± 2.73[a]	Highly resistant
	Fibre-glass	0.30 ± 0.07[c]	0.61 ± 0.05[b]	1.96 ± 0.39[c]	Highly resistant
	Kenaf (Extrusion)	0.98 ± 0.31[b]	0.86 ± 0.08[b]	12.73 ± 0.55[b]	Highly resistant
	Kenaf (Pultrusion)	0.03 ± 0.04[c]	0.34 ± 0.01[b]	1.80 ± 0.30[c]	Highly resistant
G. trabeum	Belian	3.23 ± 0.91[a]	7.87 ± 0.25[a]	43.44 ± 6.32[a]	Highly resistant
	Fibre-glass	0.31 ± 0.13[b]	0.58 ± 0.09[b]	1.94 ± 0.98[c]	Highly resistant
	Kenaf (Extrusion)	0.08 ± 0.18[b]	0.62 ± 0.03[b]	11.30 ± 0.46[b]	Highly resistant
	Kenaf (Pultrusion)	-0.01 ± 0.08[b]	0.34 ± 0.01[b]	1.83 ± 0.30[c]	Highly resistant
ANOVA (F value)					
_Support with *G. versicolour*		319.661*	5507.667*	4116.520*	
_Support with *G. trabeum*		109.727*	2680.667*	374.121*	

* indicate significant, at p=0.05. Means followed by the same letter within a column in each fungus are not significantly different by DMRT at p=0.05. The negative mean value indicates relatively small increase in weight loss of Kenaf Pultrusion post. * MC: Moisture content. Mean ± standard error

Piper nigrum Gas Exchange Characteristics

The photosynthetic rates (*A*) of plants supported by Kenaf Pultrusion, Kenafkrete and fibre-glass posts recorded higher values, which indicated better growth performance for black pepper plants supported by these types of post (Table 4). The favourable outcome from the result of net photosynthetic rate was that Kenaf Pultrusion, Kenafkrete and fibre-glass posts were able to support the growth of black pepper plants fairly well and in a similar manner as Belian hardwood. The *A* rate was reduced by 17% in black pepper plants subjected to Kenaf Extrusion compared to that of the Belian posts. The result for net photosynthetic rate of black pepper might well be associated with changes in its leaf temperature and leaf-to-air VPD (Table 4). Day (2000) and Aspinwall et al. (2016) reported that increase in leaf-to-air VPD and temperature, acting singly or interactively, reduced photosynthetic carbon gain of a plant. The negative response of *A* rate to increasing VPD in plants has been described in several studies as well (Warkentin et al., 1992; Darlington et al., 1997, Ambrose et al., 2016).

The results in Table 4 showed that the leaf stomatal conductance (*gs*) of black pepper supported by Kenaf Extrusion post declined by 39% of that of Belian. With regard to external factors, stomata responded to many environmental factors including leaf temperature and leaf-to-air VPD (Jones, 1992; Kagotani et al., 2015). Vann et al. (1994) and Marias et al. (2017) discovered significant inhibition of both *A* and *gs* rates in most plants at air temperatures >33°C, thus relating the response to the current range limits and changes that might be linked to a warming climate. Table 4 also shows that there was no significant difference ($p<0.05$) in *gs* between the Belian and other posts including Kenaf Pultrusion, Kenafkrete and fiberglass. This suggesting that leaf stomatal conductance of black pepper plants responded positively when supported by these posts.

Leaf Temperature and Leaf-to-Air Vapour Pressure Deficit (VPD)

The black pepper plants supported by Kenaf Extrusion posts demonstrated significantly higher leaf temperature compared to the plants supported by Belian, Kenaf Pultrusion, Kenafkrete and fiber-glass support posts. Kenaf Extrusion consists of mainly heat sink thermoplastic material; this might have contributed to the increase in the leaf temperature. The finding was almost similar to a study done by Sulok et al. (2015), who reported that thermoplastic materials tended to heat up during summer under heat-exposed conditions. Leaf temperatures of plants supported by Belian, Kenaf Pultrusion, Kenafkrete and fibre-glass were not significantly different, indicating that in terms of temperature microclimatic effect on the leaves, these support posts were on par with the Belian posts.

Table 4 also shows leaf-to-air vapour pressure deficit (VPD) subjected to different support posts. Leaf-to-air VPD with Kenaf Extrusion support posts recorded the highest value at 1.89 kPa while that of the Belian support posts exhibited the lowest value at 1.64 kPa. This result might be due to the surface characteristics of the Kenaf Extrusion thermoplastic material affects heat transmission into the environment. Agarwal and Gupta (2011) and Sulok et al. (2015) reported that a coarse and dull coloured thermoplastic surface is more likely to absorb and emit heat and therefore, increases the surrounding temperature compared to a lighter coloured and smooth surface. In other crops such as corn and wheat, a small increase in temperature can increase leaf-to-air VPD during exposure to extreme heat radiation (Day, 2000; Will et al., 2013; Sulok et al., 2015).

Table 4
Effect of kenaf-based composite posts on leaf photosynthetic rate, leaf stomatal conductance, leaf temperature and leaf-to-air vapour pressure deficit (vpd) of Piper nigrum

Support	Photo (µmol CO_2 $m^{-2}s^{-1}$)	Stomatal cond (mol H_2O $m^{-2}s^{-1}$)	Leaf temp (°C)	Leaf VPD (kPa)
Belian	$12.06 + 0.56^a$	$0.39 + 0.98^a$	$30.99 + 0.81^b$	$1.64 + 0.94^b$
Kenaf Extrusion	$10.02 + 0.73^b$	$0.24 + 0.72^b$	$33.97 + 0.42^a$	$1.89 + 0.78^a$
Kenaf Pultrusion	$12.49 + 0.43^a$	$0.36 + 0.39^a$	$30.83 + 0.34^b$	$1.68 + 0.46^b$
Kenafkrete	$12.58 + 0.61^a$	$0.36 + 0.55^a$	$31.31 + 0.75^b$	$1.72 + 0.32^b$
Fibre-glass	$11.91 + 0.59^a$	$0.38 + 0.87^a$	$31.60 + 0.68^b$	$1.70 + 0.55^b$
ANOVA (F value)	16.353*	8.324*	11.333*	5.668*

* indicate significant, at $p=0.05$. Means followed by the same letter down the column are not significantly different by DMRT at $p=0.05$. Mean ± standard error

CONCLUSION

In this study, the adventitious roots of black pepper plant demonstrated positive response to all types of support except the Kenafkrete posts. The laboratory decay test showed that Kenaf composite posts were highly resistant to wood decay fungi and performed better than Belian posts. For the measurement of leaf temperature and leaf-to-air VPD, Kenaf Extrusion contributed to an adverse microclimate environment for the growth of black pepper plants. The gas exchange rate of black pepper plants supported by Belian, Kenaf Pultrusion, Kenafkrete and fibre-glass were comparatively higher than that of Kenaf Extrusion. Therefore, the above findings have demonstrated that Kenaf Pultrusion and fibre-glass posts are suitable as an alternative support to Belian posts compared to those of Kenafkrete and Kenaf Extrusion. However, follow-up research is needed for further verification of the usage of Kenaf composite posts, which include aspects such as the efficiency of fertiliser use and the productivity of the plant.

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