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Short Communication

Observations on the Role of Adventitious-Root-Holdfasts in Juvenile to Adult Transition in Black Pepper

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ABSTRACT

The exogenous factors which influence the timing of transition from vegetative to adult form in different plant species include: time, (age); photoperiod; light intensity; light spectrum; temperature stress; and nutrient availability [1-3]. Observations of about 75,000 black pepper plants derived from rooted cuttings and 12,500 plants derived from tissue culture revealed that formation of functioning holdfasts, formed by adventitious roots growing from the nodes of orthotropic stems onto a solid substrate, was required before plagiotropic flowering stems were produced. In a review of the literature, we could find no references documenting the precursory role of holdfasts in the juvenile to adult transition, even though many species of woody vines and lianas exhibit juvenile to adult transition and produce adventitious root holdfasts to secure the juvenile stage to trees. This observation is important, not only for botanical science, but also for farmers producing black pepper.

Keywords: *Piper nigrum*; Black Pepper; Adventitious roots; Holdfasts; Adult-juvenile-transition

INTRODUCTION

Black pepper, *Piper nigrum* L., (BP), is the source of the world's most important spice crop. It is a woody vine with a juvenile stage of orthotropic stems, (OS's), and an adult stage of plagiotropic stems, (PS's), which are formed at the nodes of the OS's. Flowers are produced only on the PS's so the plant transition from juvenile to adult is of critical interest to BP farmers.

METHODS

A 10-ha proof of concept, (PoC), BP plantation was planted in Malaysia with about 75,000 OS rooted cuttings and 12,500 plants derived from tissue culture, of the varieties Kuching and Semongok Aman between July 2017 and September 2019 [4]. The plants were grown in a 70% shade nursery in tree bags, 8 cm diameter x 20 cm tall, filled with a mixture of 50%, v/v of cocopeat and 50% v/v BRIS sand. A split bamboo stake, 70 cm-80 cm long and 2 cm-3 cm wide was placed in each bag, and the growing plants were tied to the stakes with plastic ties, applied with a "Max Tapener" tool. At the time this work was planned and executed, we were not aware of the role of holdfasts, (HF's), in the formation of PS's, so no attention was given to securing the nodes of the OS's to the split bamboo stakes. When the plants reached a height of 40 cm-80 cm, with at least nine nodes, they were transplanted, together with the split bamboo stakes, into the PoC plantation. The PoC plantation deployed a new concept for growing BP; instead of growing the plants in the traditional manner, beside poles, pillars or live trees, a high trellis was erected with top wires at heights of 3, 4 and 5 m. Coir twine, 4 mm diameter, was attached to the top wires and to the base of the BP plants. As the BP plants grew above the height of split bamboo stakes, they were attached to the coir twine with plastic ties. 1,800 plants of the variety Kuching growing in three different media and with different fertilizer regimes were selected for recording certain growth parameters every 60 days, for the succeeding 420 days. A detailed analysis of 445 of the 1,800 plants was conducted, initially recording height, diameter at base, number of nodes on main OS's, number of PS's, and number of fruit spikes. About 13 months after transplanting, it was observed that the BP OS's growing on the coir twine, attached by plastic ties, had produced only multiple OS's, but not a single functional HF nor PS. However, OS's which were growing touching the wooden support poles, had formed functional adventitious HF's and PS's at almost every node (Figure 1). Furthermore, the internode length of the OS's attached to the poles with HF's measured 7 cm-8 cm, which corresponds to the internode lengths recorded by Chen et al. [5], for Kuching BP growing on deadwood posts in Sarawak, while the internode length of OS's attached to the coir twine had an average internode length of 4.7 cm. More than 10,000 of these OS's were pruned, some had the entire stem above a height of 80

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cm removed, and others had the terminal two nodes removed, but the pruning resulted in production of only OS's.

Attaching solid surfaces to growing OS's of rooted cuttings, and TC derived plants

Wooden stakes, 5 cm wide and up to 5 m tall, and Acacia poles 5 cm-6 cm diameter, were placed against the OS's of rooted cuttings and TC derived plants in the PoC plantation about 24 months after transplanting, by which time the OS's tied to the twine had reverted to a juvenile stage with no PS's. The nodes on these OS's were taped to the stakes and poles with plastic ties and HF's and PS's were produced in about 70 d.

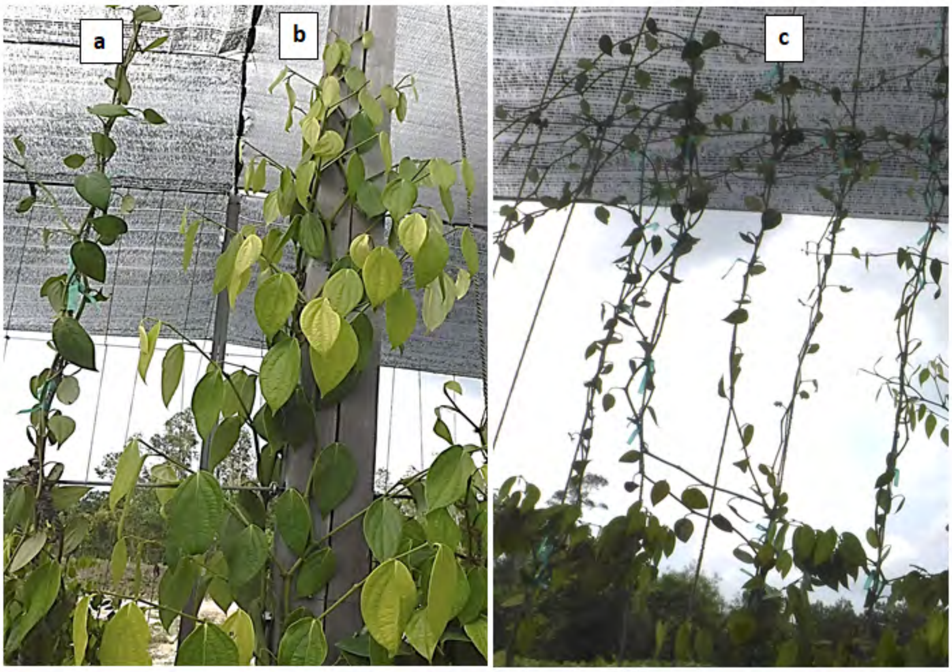

Figure 1: (a) BP growing up coir twine with no HF's or PS's and short internodes; (b) BP growing on wood post, with HF's and OS's at every node; (c) 23 months after transplanting, BP OS's growing to 6-7 m length on coir twine with no HF's nor OS's.

RESULTS

Rooted cuttings

When the 445 5 months-7 months old, rooted cutting OS plants were transplanted into the plantation it was observed that a few OS's had already formed holdfasts on the split bamboo stakes; 46.5% had PS's and 0.45% had fruit spikes. At 120 days after transplanting, (DAT), 92.6% had PS's and 7.6% had fruit spikes. When these OS's, grew above the top of 70 cm-80 cm stakes, they were attached to the coir twine. They continued to grow as juvenile OS's to a 6 m-7 m length over the next year, but they did not form any HF attachments to the twine, and they completely ceased production of PS's. The coefficient of correlation calculated for number of PS's per plant at 120 DAT, with number of functional HF's per plant was a highly significant 0.85, with 445 plants observed (Figure 2). The OS became adult and produced HF's and PS's in the first 5 months-7 months after transplanting. They then reverted to a juvenile stage when they no longer formed HF's for the next 18 months, and regained the adult stage, producing PS's when wood substrate was held against them, and they attached to the wood with multiple HF's. A diagram illustrating the sequence of changing morphology is shown in Figure 3.

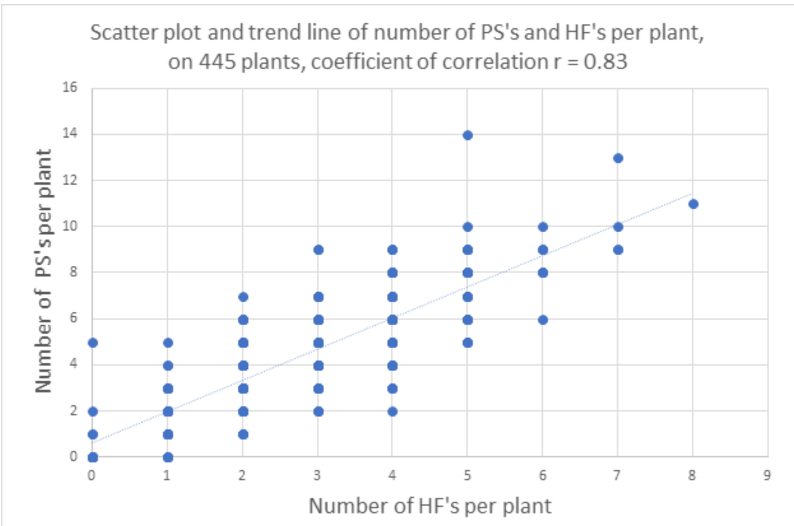

Figure 2: Scatter plot of 445 plants, showing number of HF's and PS's formed per plant 120 DAT, showing a positive coefficient of correlation of 0.83

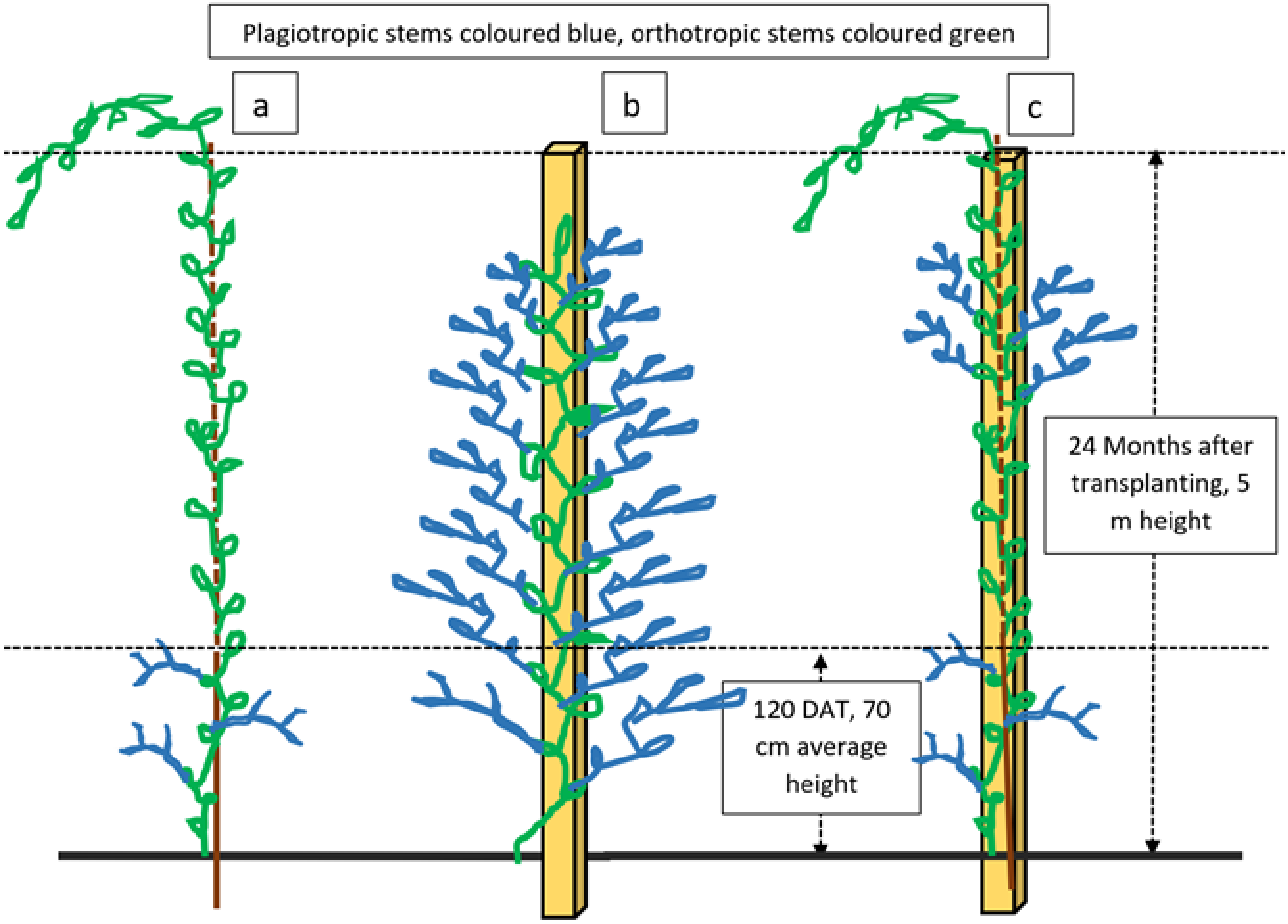

Figure 3: Diagram of different BP rooted cutting morphology growing on different support systems. (a) Plants growing on split bamboo stakes to 70 cm height 120 DAT, forms a few HF's & PS's, then grows on coir twine to 6 m-7 m height 24 months after transplanting, with no HF's nor PS's; (b) Plants growing on 10 cm square wood post to height of 4 m 24 months after transplanting, with HF's on 87% of nodes and PS's on 94% of nodes; (c) Plants growing on split bamboo stakes, then grows on coir twine to 6 m-7 m height 24 months after transplanting, then insert 1 x 2" pole against the OS and after 70 d, when HF's and PS's were formed on the top section of the OS's.

Tissue culture plantlets

During the 2 year period after transplanting, the hardened OS's derived from TC, produced no HF's nor PS's on split bamboo stakes in the nursery, nor on the coir twine after transplanting. After wooden stakes were placed against these plants, HF's and PS's were produced in 70 d.

DISCUSSION

When this project was commenced in 2015, an extensive search of the literature revealed no information on growing BP on strings, twine, or wires. As far as we could ascertain, all black pepper is farmed by placing black pepper plants against a solid vertical structure such as a large pole, a living tree, or a brick, concrete, or rock pillar. After an initial tying to the structure, the BP OS's formed HF's naturally, to climb higher on the structure. Usually, farmers pruned the first OS's after 6 to 8 months of growth, cutting the OS's to about 30 cm above the ground. This results in formation of 2 to 4 new OS's, which are allowed to grow to the maximum height of the supporting structure, when the top nodes are, removed [6]. The OS's, which are attached to the vertical structure by HF's at most nodes on the OS, formed PS's abundantly, beginning as early as 6 months after transplanting. Since all literature of PB production technology describes BP growing on a solid vertical substrate, where HF's attached the OS's to the substrate at almost every node, the role of the HF's in the transition of the plant from juvenile to adult has never been evident.

The BP derived from TC did not produce any HF's or PS's in the first 2 years after transplanting, unlike the rooted cuttings which produced a small number of HF's and PS's, and even a few fruit spikes, in the first 5 months-7 months after rooting. But the TC plants did form HF's and PS's when the top 50 cm-70 cm of 24 month old OS's was tied to wooden stakes. We might conclude that the TC plants were exhibiting a longer period of juvenility. However, BP derived from tissue culture grown in Pohnpei, Micronesia, tied to concrete pillars, exhibited higher and more precocious production of peppercorns than traditional rooted cuttings grown in the same manner [7].

In a study conducted in a greenhouse in Wageningen, BP rooted cuttings were grown up on wires, without any solid substrate or holdfast production, but these plants did produce PS's and fruit spikes in 4 months. The fertilizer regime used in the Wageningen trial had higher concentrations of fertilizer elements in the BP root zone, (F, van Noort, personal communication, December

27, 2021), than the concentrations in the root zones in the Malaysia trial. This observation leads us to believe that exogenous factor's, other than the attachment of holdfasts to a solid substrate, such as fertilizer concentration in the root zone, are also involved in the transition from juvenile to adult stage in BP. Further research should be conducted to identify and clarify the role of these factor's and their potential interactions.

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