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Use of root trainers and wick irrigation for better production of rubber plant seedlings production in nurseries

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Abstract

The conventional system of raising rubber seedlings in nurseries is the soil-polybag growing system with sprinkler irrigation. The drawback of this system is associated with high water wastage and labour. The soil-polybag growing system also causes root restriction and root coiling which reduce the seedlings growth and lower field survival rate upon field transplanting. The potting mix growing system was developed in this study to overcome these disadvantages. An experiment was conducted under a rain shelter at Field No. 15, Universiti Putra Malaysia, Serdang (2^{O}59'4.96"N and 101^{O}44'0.70"E) for 8-months period, from December 2014 to July 2015. The experiment was laid out in a RCB design. Rubber clone RRIM 2000 series at one-month old was used, under two different growing systems as follows: potting mix growing system (BX-1 growing media with Rb900 tubes) with wick irrigation system (T1) and soil-polybag growing system with wick irrigation system (T2). Plant growth parameters and leaf nutrient content of the seedlings were measured at the start and end of the experiment. Highest plant growth and leaf nutrient content was recorded in the potting mix growing system which differed significantly from the seedlings raised in the conventional system ($p<0.01$). The cost benefit analysis of the two growing systems showed that the conventional growing system had a higher cost saving benefit for a small-scale seedlings production but only for the short term. For a longer term of production or a large-scale production, the potting mix growing system had higher cost benefit more than the conventional system.

Keywords: Potting mix system, sprinkler irrigation, soil-polybag, capillary wick irrigation, rubber, nurseries

Introduction

A crop nursery is established to produce high quality and healthy planting materials with the least expenses (*i.e.*, labour and cost) and at the earliest time. Raising of young rubber plants (seedlings) is usually carried out in the nursery where they undergo desired and necessary manipulations (such as budding) (Aghughu and Oghide, 2012). In the past, rubber seedlings were raised mostly in newly cleared forest areas, but today, due to the massive conversion of forest to non-agricultural uses, raising rubber seedlings now occur on marginal land areas (Waizah *et al*., 2011).

The growth of rubber seedlings is influenced by the condition of their production. The factors affecting the production of rubber seedlings includes: the quality of the growing medium, irrigation, drainage and fertilization. Successful greenhouse and nursery production of container grown seedlings is largely dependent on the chemical and physical characteristics of the growing media (Robbins and Evans, 2011). Seedlings are being raised in polybag in many parts of the world. However, seedlings raised in polybags suffer from many disadvantages. The seedling stocks produced in polybags, for instance, experienced problems of root coiling, distortion and transplanting shock (Sharma, 1987). The use of potting mix growing system has an advantage of overcoming the problems caused by soil polybag system (Salisu *et al*., 2013; Nabayi *et al*., 2018).

The most limiting and most variable environmental factor affecting productivity of plants is water (Field and Solie, 2007). Wick irrigation is an alternative irrigation system which uses capillary action whereby the movement of water form a reservoir is transported directly into the container substrate via an absorbent wick (Figure 1). Wick irrigation was first introduced in India. It was used in conjunction with buried clay pot irrigation (Mari-Gowda, 1974; Bainbridge, 2001).

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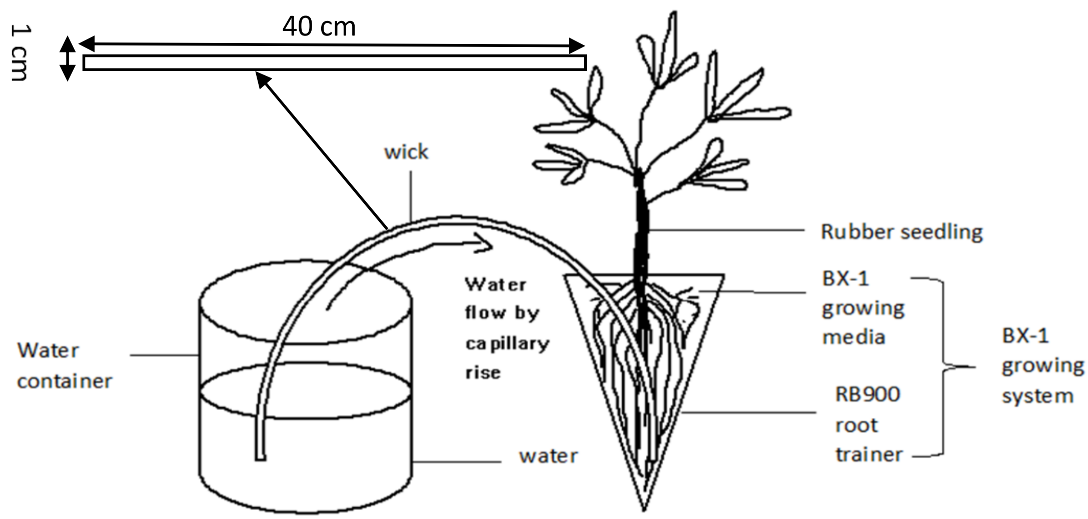

Figure 1: Wick irrigation system

The wick system is being used in areas of high evapotranspiration, such as tropical and sub-tropical countries (Ritchey and Fox, 1974). The method is also used for other research purposes for its ability to maintain a selected soil moisture continuously (Marrone, 1982; Stalder and Pestemer, 1980). In this system, water and nutrients are replenished to the container (root trainer) filled with growing media via capillary action of the wick (Toth *et al*., 1988). Bryant and Yeager (2002) claimed that capillary wick irrigation compared with overhead irrigation reduces cumulative irrigation volume by 86% without sacrificing the plant growth. Hunt and Madsen (2002) found that wick had successfully reduced or eliminated runoff. Although this system offers many advantages like reducing labour, continuous water supply and ability to control the temperature of the rooting medium, it however also has its own disadvantages, such as excessive evaporation, leakage from water container and algal growth on the wick (Dolar and Keeney, 1971; Toth *et al*., 1988).

In Malaysia, there are no alternative techniques for establishing rubber seedlings in the nursery apart from the conventional (soil-polybag) system. Although compost is being used recently (Nabayi *et al*., 2018). Labour is the main limiting factor in the conventional system as it comprised not less than 80% of the total cost involved in the nursery production system (Josiah and Jones, 1992). Irrigation water is often in short supply, and the conventional system of irrigating the rubber seedlings is the sprinkler which has high water loss. Many potting mix and root trainers are being introduced with the purpose of replacing the traditional (Soil-polybag) system of raising seedlings (Nabayi *et al*., 2018). The introduction of the growing media should bring many benefits such as: lighter in weight and more compact and eco-friendly as the container used with the media can be reused, improved root growth, and reduction in labour work due to more efficient design and easier handling. In contrast, the usual conventional polybag causes negative impacts to environment because the polybag cannot be reused and takes longer time to disintegrate, the use of more space and a heavier media because soil is used as the growing medium (Bunt, 1988).

The objective of the research was therefore to compare the growth, nutrient contents and water use of rubber plant seedlings grown in soil and in potting mix. The research also aimed at calculating the cost-effective techniques to be used in raising rubber seedlings through these two systems: potting mix and soil polybag.

Materials and Methods

Experimental site, materials used and Treatments

The research was conducted in a rain shelter facility (2^{O}59’05.0”N 101^{O}44’00.9”E), (Field No. 15), Faculty of Agriculture, Universiti Putra Malaysia (UPM), Serdang, Selangor . A rain shelter with transparent roof and covered with black net to avoid water supply from rain and lower the intensity of the solar irradiance reaching the young rubber seedlings respectively, was used. BX-1 is a potting mix formulated purposely for raising rubber seedlings but there is no proper trial conducted on its performance on the rubber seedlings growth. It is manufactured by Peltracom company at Latvia. The main composition is 100%

neutralized white peat as claimed by the company, which has been treated with lime and slow release fertilizer to suit the needs of the crop, and as such we decided to use the BX-1 as our potting mix. Rb900 root trainer allows plant roots to grow downward and prevents spiral growth (Wong *et al*., 2013). Rb900 (Figure 2) was used in the research based on its design and previous studies (Wong *et al*., 2013; Nabayi *et al*., 2018). About 230 g of fresh potting mix was used per tube and 8 kg of Munchong soil series (Tropeptic Haplorthox) per polybag for potting mix and soil-polybag growing systems, respectively. The root trainer has a dimension of top diameter, bottom diameter and length of 6.7 cm x 2.29 cm x 29 cm, respectively. It is black in colour with a volume and thickness of 800 mL and 2 mm, respectively. Twenty five gram (25 g) of powdered rock phosphate was used as starter during transplanting in the polybag system which was followed by a regular fertilizer (N-P-K-Mg 10-10-4-1.5 mixture) application as outlined in Noordin, (2013). The treatments (with three replications each) were Potting mix growing system (T1) and soil-polybag growing system (T2). Sixty (60) rubber seedlings were used in the research with 10 seedlings per replication. The treatments were laid in RCB design. RRIM 2000 series clone obtained from MARDI (Malaysian Agricultural Research Development Institute) was used in the experiment.

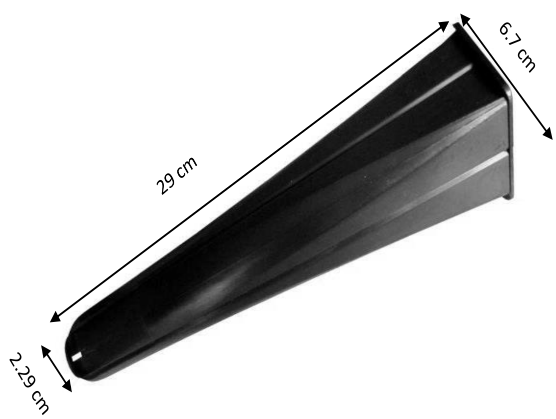

Figure 2: Rb900 root trainer

Irrigation was applied once a day in the morning. The irrigation method used was the capillary wick system, which is a self-watering system where a sufficient amount of water was measured and put in the water container every day and the water was taken by the wick via the action of capillary and led to the roots of the rubber seedlings (Figure 1). The water level in the container was checked every day to determine how much water had been removed from the container. The wick material was made from cotton and the width and length of the wick used were 1 cm by 40 cm respectively. The PVC container has a length and internal diameter of 50 by 10 cm with a capacity of approximately 1.5 litres. From DAT to the harvest day, a range of 19-136 mL of water is going into the root trainer every day.

The concept used by Heydari (2014) for calculating water productivity (WP) and water use efficiency (WUE) was adopted as follows:

$$WP = \left(\frac{Total\ dry\ weight\ (g)}{Cumulative\ transpiration\ (L)}\right) \quad (1)$$

$$WUE = \left(\frac{Amount\ of\ water\ used\ by\ the\ plants\ (L)}{Output\ of\ the\ irrigation\ system\ (L)}\right) \quad (2)$$

Physical and chemical properties analyses

Physical and chemical properties of both soil and the potting mix were analyzed. Plant growth parameters were measured and recorded at the end of the experiment. Destructive samplings were also taken for leaf nutrient analysis and leaf area. Leaf sampling was conducted according to the Malaysian Rubber Board guidelines, where four basal leaves from the first sub-terminal whorl were collected (RRIM, 1990). The samples were oven dried at 60 ^{O}C for 5 days. The leaf samples were used for N, P, K, Ca and Mg determination. N was determined using CNS analyser (LECO TruMac® CNS, USA) (Nelson and Sommer, 1982), while P, K, Ca and Mg were prepared by dry ashing method and the filtrate were sent for P and K, Ca, Mg determination using AA (Quikchem FIA 8000 series, LACHAT instrument, USA) and AAS (Perkin-Elmer, 5100PC, USA), respectively (Chapman, 1965).

Core method (Blake and Hartge, 1986) was used to determined soil bulk density while potting mix media bulk density was determined by oven drying a known quantity of the media in relation to the total volume of the tube (Rb900). Moisture contents of the soil and media was determined by subtracting the oven dry weight from the fresh weight divided by the fresh weight of the soil or media as shown in equation 5. Saturation point of the media was considered as total porosity of the media (Walczak *et al*., 2002). Soil total porosity was calculated by using the bulk density values assuming the particle density of mineral soils (2.65 Mg m^{-3}), using the following equation (Baver *et al*., 1972).

$$Bulk\ density = \left(\frac{weight\ of\ soil, oven\ dried\ at\ 105^{O}C}{volume\ of\ fresh\ soil}\right) \quad (3)$$

$$Total\ porosity = 1 - \left(\frac{bulk\ ensity}{particle\ density}\right) \times 100 \quad (4)$$

$$Moisture\ content = \left(\frac{fresh\ weight - oven\ dried\ weight}{fresh\ weight}\right) \times 100 \quad (5)$$

Klute and Dirksen (1986) constant head method was used to determine saturated hydraulic conductivity of both BX-1 media and soil. Water retention was determined using the pressure plate and pressure membrane (Richards, 1947).

Table 1: Physical and chemical properties of soil and Bx-1 media

Physical properties	Soil	BX-1 media	Chemical properties	Soil	BX-1 media
Bulk density (Mg m^{-3})	1.43	0.14	pH	4.67	6.40
Moisture content (g g^{-1})	18.10	58.00	EC (dS m^{-1})	0.04	1.22
Saturation (m^3 m^{-3})	0.56	0.95	CEC (cmol kg^{-1})	8.32	63.21
Field capacity (m^3 m^{-3})	0.29	0.31	C (%)	1.38	34.25
Permanent wilting point (m^3 m^{-3})	0.21	0.20	N (%)	0.13	1.09
			S (%)	0.03	0.75
Total porosity (%)	46	95	C:N	10.60	27.01
Hydraulic conductivity (cm h^{-1})	8.20	32	P (ug g^{-1})	8.34	680.57
			K (ug g^{-1})	41.27	1779.00
			Ca (ug g^{-1})	459.33	6223.67
			Mg (ug g^{-1})	85.47	1709.33

Table 2: Means (±standard error) of fresh weight of total and different parts of rubber plant seedlings as influenced by different growing systems

Growing system	Total fresh weight (g)	Leaves fresh weight (g)	Stem fresh weight (g)	Root fresh weight (g)
Potting mix system	129.3 ± 1.21a	40.5 ± 0.62a	69.0 ± 0.76a	29.8 ± 0.3a
Soil-polybag system	114.5 ± 3.89b	31.4 ± 2.1b	63.6 ± 2.21b	19.5 ± 2.67b
Probability level	*	**	*	**

Table 3: Means (±standard error) of dry weight of total and different parts of rubber plant seedlings as influenced by different growing systems

Growing system	Total dry weight (g)	Leaves dry weight (g)	Stem dry weight (g)	Root dry weight (g)
Potting mix system	46.4 ± 0.36a	12.1 ± 0.02a	27.3 ± 0.33a	8.3 ± 0.03a
Soil-polybag system	36.8 ± 1.64b	8.2 ± 0.21b	24.3 ± 0.72b	6.2 ± 0.58b
Probability level	**	**	*	*

Means with same letters within the same column are not significantly different from one another at 0.1%, 1% and 5% (, **, and ***), respectively.

Table 4: Means (±standard error) of total leaf area, girth size, water productivity and water use efficiency of rubber plant seedlings as influenced by different growing system

Growing system	Total leaf area (cm^2)	Girth size (mm)	Water productivity (g L^{-1})	Water use efficiency (L L^{-1})
Potting mix system	1617.4 ± 8.16a	18.2 ± 0.14a	27.4 ± 0.68a	0.65 ± 0.07b
Soil-polybag system	1323.5 ± 48.97b	14.6 ± 0.34b	18.9 ± 0.91b	0.84 ± 0.04a
Probability level	***	**	**	*

Means with same letters within the same column are not significantly different from one another at 0.1%, 1% and 5% (, **, and ***), respectively.

Table 5: Means (±standard error) of root length, root volume, root surface area and root diameter of rubber plant seedlings as influenced by different growing systems.

Growing systems	Root length (cm)	Root volume (cm)	Root surface area (cm^2)	Root diameter (mm)
Potting mix system	706.2 ± 6.89a	3.7 ± 0.08a	174.0 ± 1.00a	0.9 ± 0.01a
Soil-polybag system	532.0 ± 17.02b	3.2 ± 0.05b	158.3 ± 2.93b	0.9 ± 0.01a
Probability level	**	*	*	ns

Means with same letters within the same column are not significantly different from one another at 0.1%, 1% and 5% (, **, and ***), respectively, ns-not significant.

Table 6: Means (±standard error) of phosphorus, potassium, calcium and magnesium of rubber plant seedling leaves as influenced by different growing system

Growing systems	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Potting mix system	4.01 ± 0.31	0.39 ± 0.02a	0.92 ± 0.06a	0.57 ± 0.03a	0.19 ± 0.00a
Soil-polybag system	3.89 ± 0.50	0.21 ± 0.01b	0.65 ± 0.02b	0.44 ± 0.05b	0.14 ± 0.03b
Probability level	ns	*	**	**	**
†Sufficiency level	3.71-3.9	0.21-0.27	1.0-1.6	0.5-0.6	0.26-0.29

Means with same letters within the same column are not significantly different from one another at 0.1%, 1% and 5% (, **, and ***) respectively ns-not significant. † Noordin (2013)

Soil C, N and S were determined by CNS analyser while leaching method was used for CEC and exchangeable bases determination (Chapman, 1965) using auto analyser (AA) and atomic absorption spectrophotometer (AAS). BX-1 media total C, N and S was also determined by CNS analyser (Nelson and Sommer, 1982). Total P, K, Ca and Mg were extracted by dry ashing method. AA and AAS were used to determined P and K, Ca, Mg, respectively. The CEC of the BX-1 media was determined by shaking method (Fauziah *et al*., 1997).

Data analysis

All the data collected were subjected to SAS (2011). Independent T-test was employed in evaluating the means of the two establishment techniques and Least Significance difference (LSD) was used to detect significant difference between the means at 5% level.

Results and Discussion

Physical and chemical properties of the soil and potting mix media is shown in Table 1. The results showed that the media had a very low bulk density and higher total porosity of 0.14 Mg m^{-3} and 95% respectively. The media also had higher moisture content of 58% more than the soil which had only 18.1%. The properties of the potting mix given above are within the range of values (0.1-0.5 Mg m^{-3} bulk density, 50-80% moisture content and 50-96% total porosity) given by Xuehui and Jinming, (2010). Higher porosity and lower bulk density are very important characteristics of growing media as they allow the root of a plant to grow without restriction, in other word, higher bulk density and lower porosity of the soil can limit the root growth of seedlings. There is high water demand for rubber plant seedlings at an initial growth stage. The potting mix had higher water storage capacity as well as higher water availability for plant use (11%) more than the Munchong soil (8%) despite been a first-class soil for rubber production in Malaysia (Noordin, 2013). Higher pH and EC of the media was due to the industrial treatment of the media with lime and fertilizer to suit the needs of a rubber seedlings. In terms of macro and micronutrients, highest was obtained in the media with very high CEC which is a measure of nutrients fertility. Lower pH of the soil is an important chemical property that indicates low native fertility which make the soil less productive (Tessens and Shamshuddin, 1983). Shamshuddin and Fauziah (2010) reported that tropical soils (Ultisols and Oxisols) need soil amendments to improve the structure and fertility of these soils.

Significant difference was detected in the rubber seedlings that were raised under the two different growing systems in terms of growth parameters (Table 2, 3 and 4). Highest parameters were obtained in the seedlings raised in potting mix system which differed from those raised in the conventional growing system. There was no significant difference (p>0.05) in the seedlings raised under the two different systems in terms of plant height and leaf number. Higher fresh and dry weight of total and different parts of the rubber plant seedling grown in the potting mix system could be due to the higher moisture availability of the media. It could also be attributed to higher nutrient contents of the media as compared to the soil since the same irrigation method had been used for the two growing systems. Methods of irrigation affect the plant growth differently (Argo and Biernbaum, 1994). Higher girth size and total leaf area in the potting mix growing system seedlings were due to the water and nutrients availability in the system as compared to the conventional system since the seedlings received the same temperature and solar radiation. An important factor that determines latex yield capability of a rubber plant in terms of latex flow is the girth size (Salisu *et al*., 2013).

Water productivity (WP) is the quantity of biomass produced in relation to the amount of water consumed while water use efficiency (WUE) is the quantity of water utilised by the seedlings per unit total amount of water supplied (Heydari, 2014). Seedlings raised in potting mix growing system had higher water productivity (27.4 g L^{-1}) which differed significantly from those that were raised using the conventional growing system (18.9 g L^{-1}) as shown in Table 4. Higher WP in the potting mix system was due to the higher total dry weight (Table 3) of the seedlings more than in the conventional system. The conventional system had significantly higher WUE of 0.84 L L^{-1} while the potting mix system had 0.65 L L^{-1}. Higher WUE in the conventional system was attributed to the higher volume of soil used (8 kg) on one hand and also due to the moderate hydraulic conductivity of the soil (8.2 cm h^{-1}) on the other hand, which made the system store most of the water supplied. On the other hand, the potting mix system used only 230 g of media per tube together with very rapid hydraulic conductivity of the media (32 cm h^{-1}) which lead to higher amount of leachate in the system. The research agreed with Brar *et al*. (2012) who reported higher water productivity and grain yield by adopting water saving practices. The findings also agreed with Teh *et al*. (2015) who reported higher WP and WUE of water spinach (*Ipomoea reptans*) raised in the growing system involving root trainers and a potting mix with wick irrigation system as compared with potting mix with sprinkler system of irrigation.

Table 5 and 6 showed the effect of different growing systems on plant root growth parameters and leaf nutrient content of rubber nursery seedlings after 8 months. Highest root length, root volume and roots surface area were recorded in those seedlings that were raised in potting mix growing systems which differed significantly from those raised in the conventional growing systems. But there was no significant difference in terms of root diameter between the treatments. Potting mix growing system had higher root growth parameters due to the Rb900 (root trainer) influence which directly encouraged the seedlings root to grow vertically downward with less root restriction. Better seedlings root performance was also due to potting mix influence because of its higher porosity and light in weight that allows the roots to penetrate easily on one hand, and it could also be due to the moisture and nutrients availability of the media which are necessary for the root growth on the other hand. Conventional rubber seedlings growing system had lower root growth parameters because of the roots restriction and also due to the lower water and nutrients availability as compared to the potting mix growing system. When moisture is available, roots restriction can imitate the soil moisture stress effect (Krizek *et al*., 1985). When seedling root experienced root restriction in the nursery, even after field transplanting it is difficult for them to compensate for evapotranspiration even if they are well watered (Aloni *et al*., 1991).

Higher leaf nutrient contents of the seedlings were also recorded in the potting mix growing system which differed significantly (p<0.01) from the conventional growing system raised seedlings (Table 6). But there was no significant difference (p>0.05) between the treatments in terms of N contents. Higher nutrients availability of the media (Table 1) was the main factor for the higher leaf nutrients content of the seedlings grown in potting mix system. The irrigation system used for the two growing systems is known to supply water slowly to the growing medium, which ensures its maximum utilisation by plant (Nabayi *et al*., 2016). This water also dissolved the media and soil nutrients for plant uptake as the nutrients need to be in solution before they can be taken up by the plants and as such any difference in the leaf nutrient contents can be attributed to the differences in the growing media nutrient contents since the seedlings were raised under the same environmental condition. Lower nutrient contents of the seedlings in the conventional system was reflected in the plant growth parameters (Table 2, 3 and 4). Adequate amounts of nutrients are required for plant growth as they are the key to soil fertility (Dreyfus *et al*., 1987). Table 5, 6.

Cost benefit analysis of potting mix growing system

Table 7 shows the prices of different rubber seedlings growing systems' component. The cost of labour was RM 6 man^{-1} $hour^{-1}$ and the Rb900 and polybag filling time ratio is 3:1. Each Rb900 was filled in 45 seconds while 2.25 minutes averagely was taken to fill a polybag as the soil need to be dug at times. The manufacturers claimed Rb900 and planting tray have a minimum lifespan of 8 years.

Table 8 shows the cost analysis of potting mix system of planting rubber nursery seedlings as compared with conventional (soil-polybag) system of raising rubber seedlings in 100 m^2 area for the first year. The analysis took into consideration only what it takes to have the systems ready for planting or transplanting (systems components). The analysis of the research indicated that the potting mix system has higher initial cost of production because all the components have to be purchased which were more expensive compared to the soil-polybag (conventional) system, while the major expenses in the conventional system is labour which amounts to 47% of the total expenses as compared to the less than 5% of the potting mix system. The result shows that the potting mix system had higher system component cost of Ringgit Malaysia (RM) 7395 as compared with conventional system which had only RM247, but the potting mix system had higher number of seedlings that can be produced per 100 m^2 ground area (Table 8). For the conventional system, labour was the main cost unlike in the potting mix system, where labour comprised less than 5% of the total cost. The Soil-polybag needs more floor space, and the higher soil volume would be more difficult to handle (Josiah and Jones, 1992). After considering the cost of all the components involved in the two systems, the conventional system (soil-polybag) has a less total expenditure and cost benefit savings (Net profit) of 96.6 and 43.6%, respectively over the potting mix growing system in the first year. However, from second year onwards as shown in Table 9, the potting mix system would have 72.2% cost savings benefit than the conventional system due to the higher number of seedlings produced for a minimum period of 8 years.

Thus, the conventional system's cost will remain the same every year because of the cost of labour and the polybag. Most of the potting mix system components can be used and reused for a minimum period of 8 years, so, the only additional costs in the successive years for the potting mix system are the cost of media and labour. The major objectives of nurseries are to produce healthy, vigorous and good quality seedlings, and at the same time to minimise the cost of their production (Aghughu and Oghide, 2012; Qaisar and Mishra, 2005). Despite the higher initial cost involved in the potting mix system, which were recovered by the higher number of seedlings produced by the system in the first year, the system will have a cost-benefit of 72.2% over the conventional system from the second year onward (Table 9) in 100 m^2 area.

More seedlings per ground area will be produced if potting mix system is used rather than conventional system.

Table 7: Cost of the systems' components as at 6-Jan 2016

No.	Item	Quantity	Cost (rm)[1]
1	BX-1 media	1 bale	180
2	Planting stand set	1 carton	375
3	Rb900 (160 tubes)	1 carton	336
4	Polybag	1 kg	24
5	Labour Cost of filling Rb900	100 tubes	7.50
6	Labour Cost of filling polybag	100 polybags	22.5

[1]RM1 is approximately USD 0.24

Table 8: Cost benefit analysis of Potting mix system against soil-polybag system per 100 m^2 area in the first year (RM1 is approximately USD 0.24)

Description	Quantity	Unit price (RM)	Total Price (RM)	Savings (%)
Potting mix system				
BX-1 media	10 bale	180	1800	
Planting stand set	1 carton	375	375	
Rb900	15 cartons	336	5040	
Cost of filling Rb900	2400 pcs	0.075	180	
No. of seedlings produced	2400	3.5	8400	
Total Cost			(7395)	
Net profit			1005	
Soil-polybag System				96.6
Polybag	580	0.2	116	
Cost of labour	580	0.225	131	
No. of seedlings produced	580	3.5	2030	
Total Cost			(247)	
Net profit			1783	43.6

Table 9: Cost benefit analysis of Potting mix system against soil-polybag system per 100 m^2 area from second year onwards

Description	Quantity	Unit price (RM)	Total Price (RM)	Saving (%)
Potting mix system				72.2
BX-1 media	10 bale	180	1800	
Cost of filling Rb900	2400 pcs	0.075	180	
No. of seedlings produced	2400	3.5	8400	
Total Cost			(1980)	
Net profit			6420	

Seedlings raised in root trainers have higher out planting survival rate than the polybag raised ones because of less transplanting shock (Sharma, 1987). Root trainers need smaller amount of growing media which are less heavy, occupy less space, produce more seedlings per hectare and easier to transport to the main planting site than the soil-polybag system (Wong *et al*., 2013; Altamash *et al*., 2009). Table 7, 8, 9.

Conclusions

The root trainer (Rb900) as component of a potting mix growing system was able to overcome soil polybag problem with its unique features that encourage the root growth vertically. The study showed that the potting mix growing system is the better system than the conventional system currently being used to be adopted for raising rubber nursery seedlings. The higher amount of leachate volume obtained in the potting mix could be minimised by using shorter wick. The cost analysis further strengthens the superiority of the potting mix system over its counterpart due to the lower labour demand of the system (<5%), which made it to have a higher cost saving at long run. Labour was the main cost involved (>45% of the total cost) in using the conventional growing system and because of the bulkiness of the soil which occupies larger space in the nursery, less number of seedlings are produced per unit area which makes it necessary to have an alternative growing system that will minimize the cost and increase the seedlings production per unit area.

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