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Comparison of Three Irrigation Systems for the BX-1 system for Nursery Seedlings

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ABSTRACT

The BX-1 system (consisting of the BX-1 media and RB 900 tube) is a new planting system introduced by a private company to replace the growth of plants in soil-filled polybags. Different irrigation systems influence plant growth differently. The main objective of this study was to compare and determine the best of three water irrigation systems: overhead sprinkler (SPR), drip (DRP) irrigation, and the capillary wick (WCK) system, for the BX-1 system. The test crop was water spinach (I*pomoea reptans*), and the performance of these three irrigation systems was compared with one another in terms of their effects on plant growth, amount of water and nutrient losses via leaching, water productivity and water use efficiency. The field experiment was carried out under a rain shelter at Field No. 15, Agrobio Complex, Universiti Putra Malaysia (2^o 59’ 4.96” N, 101^o 44’ 0.70”E), for 5 weeks from July to August, 2014. The experimental layout was the RCBD with the treatments being the three irrigation systems with three replications per treatment. Each experimental unit was planted with 20 water spinach plants. Results from the study showed that the capillary wick system produced the least leachate volume and nutrients loss. In terms of growth, the WCK system gave the highest growth for roots dry weight and leaf area. This was because the WCK treatment had the lowest amount of leachate and nutrient losses, so it had the highest nutrient content in the plant for N, P, and K, but there was no difference (p>0.05) in the Ca and Mg content. WCK also had the highest water use efficiency, but there was no difference in water productivity between the three treatments. WCK consumed the highest amount of water (but had least water wastage) to produce the highest amount of roots biomass and leaf area compared to DRP and SPR treatments. Thus, it is suggested that the WCK system be used with the BX-1 system as it was found to be the most effective irrigation system.

Keywords: **BX-1 media, RB 900 tube, overhead sprinkler, drip irrigation, capillary wick irrigation.**

INTRODUCTION

Plant growth potential is largely controlled by the environment that the media provides for root growth. Roots need water, air, nutrients and enough space

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to develop (Nageswara and Jessy, 2007). Choosing the most suitable growing media for the achievement of successful plant production is very important in tube growth. Enough water application to plants generally eliminates water stress, which affects all plant functions including water and nutrient uptake. The important criteria for successful rooting is a reliable rooting medium. Growing media are the materials similar to soil that physically support plants growth. A balance between available water and aeration in the growth medium is essential for production of quality plants in containers (Ekpo and Sita, 2010). The use of alternative soilless media for the production of potted plants needs an understanding of their physical and chemical behaviour to select the appropriate conditions for plant growth. Ornamental plants require growing media with adequate water retention and aeration (Erstad and Gislerod, 1994) and routine fertilisation that guarantees continuous nutrient supply (Macz *et al.*, 2001).

BX-1 media, made from Latvia, and imported into Malaysia by a private company, consists of 100% neutralised white peat, treated with an unstated slow releasing fertiliser and lime. Wong *et al.,* (2013) reported that oil palm seedlings raised under a semi-float condition in the BX-1 system had significantly greater plant height, more leaves and longer leaves compared with those obtained in the polybag system.

RB 900 tube (Figure 1) is another form of root trainer which is a rigid container with internal vertical ribs, which direct roots straight down to prevent spiral growth. The containers are set on frames or beds above the ground to allow air-pruning of roots as they emerge from the containers.

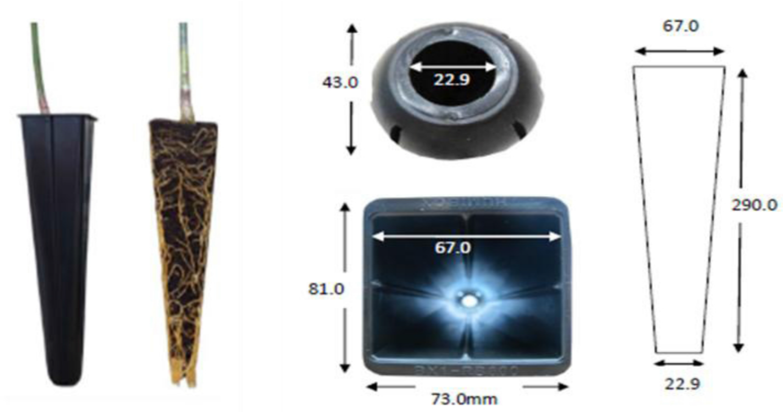

Figure 1: RB 900 tube courtesy of Humibox (M) Sdn. Bhd

Due to abundant rain, most soil nutrients are leached from the soil and as a result, the plant could face nutrient deficiency. So selecting the best irrigation system with proper time scheduling is one solution.

Water is an essential element for plant growth. Each crop needs an optimum amount of water for growth and development. In arid regions, irrigation is the main source of water for agricultural production while in semi-arid regions, much of agriculture depends on unreliable rainfall. Depending on rainfall alone may not be sufficient to provide the much needed water to crops. Because of the uncertainty of rainfall, irrigation is required. In fact, irrigation may be the only way to maintain high and sustainable agricultural productivity. Irrigation water has always been in short supply, and it is becoming a scarce commodity in many regions and even where it is available, the cost of pumping and/or transportation may be high in many locations; moreover water loss varies across irrigation systems. The growth of rubber seedlings is greatly influenced by their production conditions and these range from irrigation, soil or substrate quality, to drainage and fertilisation. BX-1 system (RB 900 tubr and BX-1 growing media) is a new nursery planting system, that aims to replace the traditional (polybag with soil) way of raising seedlings. Utilisation of container nurseries are being developed rapidly in Malaysia and the world at large, because it gives better productivity and better production of nursey seedlings. Different water application methods affect the growth of nursery seedlings regardless of source and rate of nutrient solution (Argo and Biernbaum, 1994). The benefits of growing seedling in containers are several: easy handling and transportation, less space, rapid product rotation and easy marketing. Hence this system is being adopted over field production. The introduction of BX-1 system brings several benefits such as light weight and compact design, eco-friendly as the container can be reused, and a reduction in labour work due to efficient design and easy handling. In contrast, the old conventional polybags cause negative impact on the environment because they cannot be reused and take longer time to disintegrate. Others limitations of soil-filled polybag system includes occupation of more space and heaviness.

Water spinach was used as a test crop because of its ability to grow very fast and its high demand for water and nutrients. The main objective of the study was to compare three irrigation systems (overhead sprinkler, drip irrigation, capillary wick system) for use in BX-1 system with water spinach as a test crop. The irrigation systems were compared with one another in terms of their effects on the growth, nutrient content, water use efficiency and productivity of water spinach grown on BX-1 system.

MATERIALS AND METHODS

The experiment was carried out in Field No. 15 Agrobio Complex, under the rain-sheltere (2°59'4.96"N and 101°44'0.70"E) in the Faculty of Agriculture, Universiti Putra Malaysia, Serdang, Selangor. Water spinach (*Ipomoea reptans)* was planted in 710 cm^3 RB 900 tube filled with 180 g of BX-1 media (white peat) as a test crop. The exact composition of the media is a trade secret; information on the media was obtained from the bag label. Each tube was planted with four seeds, after which two were removed (leaving two plants) one week after germination. The field experiment was carried out for five weeks from July to August 2014.

The study was conducted in a Randomized Complete Block Design (RCBD) with three replications and three treatments: T1= Overhead Sprinkler Irrigation (SPR); T2= Drip Irrigation (DPR); and T3= Capillary Wick Irrigation (WCK). Each experiment plot consisted of single tray or tube stand that accommodated 10 RB 900 tubes with 2 water spinach (*Ipomoea reptans*) seedlings. The total number of water spinach seedlings used were 20 plants per plot x 9 plots or 180 plants.

Each tray stand measured 1.5 m long and 0.5 m wide. Within the experimental block, each treatment was separated from the other by a width of 1.6 m, and by a length of 3.1m between the blocks. The total area of the experiments was about 50.29 m^2 (borders excluded). Water flow from the overhead sprinklers was adjusted in such a way as to prevent the water falling onto the neighbouring plots. A plastic sheet was attached around the rain shelter to stop crosswind that might disturb the distribution of water during irrigation by the overhead sprinklers. Irrigation was carried out daily in the mornings for all treatments except the capillary wick system. A daily total of 45 mL of water was supplied to each seedling under SPR and DRP while for WCK, a known amount of water was applied every day in the PVC, to allow the wick to supply the water to the plants because it is a self watering system. The PVC was emptied every day in order to determine how much was taken up by the plants; the water uptake averaged 53 mL per day per tube. Water uptake in the capillary wick system could not be controlled as it is a self watering system where there is continuous water uptake through the wick via capillary action.

Physical Properties

The water content in growing media was measured using a moisture meter (FieldScout TDR 100-6440FS, Spectrum Tecnology, Inc., USA) every week to monitor the moisture status of the media. The BX-1 media was analysed for its physical and chemical properties.

In terms of physical analysis, bulk density, moisture content, total porosity and water retention of the media were determined. Bulk density was determined using the core method (Blake and Hartge, 1986). Water retention was determined using the pressure plate and pressure membrane described by Richards and Fireman (1943) and Richards (1947).

Chemical Properties

Total C, N and S was measured using CNS analyser (Nelson and Sommers, 1982). Total P, K, Ca and Mg were analysed using dry ashing method. Autoanalyser (AA) was used to measure total phosphorus (P) while the content of potassium (K), calcium (Ca) and magnesium (Mg) content was analysed using the atomic absorption spectrophotometer (AAS). Cation exchange capacity (CEC) and exchangeable bases were determined by leaching method using 1 M NH_4OAc (pH 7) method (Thomas, 1982). The displaced exchangeable bases and NH_4^+ were determined using the AA and AAS. The pH and EC were also determined in water using 1: 5 media: solution ratio.

For each week for the five weeks of the experiment, leachate was collected from each tube, pooled, and then analysed for volume of leachate and N, P, K, Ca, and Mg nutrient content after filtering. The nutrients N and P were analysed using autoanalyser and nutrients K, Ca and Mg using AAS. The same leachate was also measured for pH and EC.

Each week, plant samples from two tubes in each experimental unit were destructively measured for their fresh and dry weights (leaves, stem, and roots), leaf area, plant height, and plant nutrient content (N, P, K, Ca, and Mg).

Nutrients in plant tissue were determined using wet digestion method (Jones, 2001). The N, P, K and Ca, Mg contents were determined by AA and AAS respectively.

All data collected were tested using the statistical analyses system (SAS 9.4 SAS system for windows by SAS Institute Inc., Cary, NC, USA). Analysis of Variance(Anova) was used to determine the significant treatment effect on various measured properties with the significance set at $p<0.05$. Student –Newman-Keuls (SNK) test for means separation was used to detect significant difference between means.

RESULTS AND DISCUSSION

The result of the BX-1 physical properties (Table 1) showed the media to be very light (0.135 Mg m^{-3}), with about 60% water. It has 0.04 m^3 m^{-3} of available water. Porosity is one of the most important physical properties in a growing media because it determines the space available in a container for air (aeration), water, and root growth (Bunt, 1988). Aeration is important because the root system "breathes" (exchanges oxygen and carbon dioxide) in the large, air-filled pores (macropores). Poor aeration will adversely affect root form (morphology) and structure (physiology) and will lead to decreased seedling vigour (Scagel and Davis, 1988).

TABLE 1
Physical and chemical properties of BX-1 media

Physical property	Value	Chemical property	Value
Bulk density (Mg m^{-3})	0.106	pH	5.54
Moisture content (g g^{-1})	0.582	EC (dS m^{-1})	0.90
Saturation (m^3 m^{-3})	0.59	CEC ($cmol_+$ kg^{-1})	63.23
Field capacity (m^3 m^{-3})	0.27	C (%)	41.48
Permanent wilting point (m^3 m^{-3})	0.23	N (%)	1.41
		S (%)	0.75
Total porosity (%)	57	C:N	29.42
		P (%)	0.32
		K (%)	0.66
		Ca (%)	1.02
		Mg (%)	0.35

The result of the chemical properties (Table 1) showed that the pH of the media is within the desired range with most of the nutrients being available for the plants. An increase in EC of the bulk solution in the growing medium suggests that the fertiliser applied is more than what the plant can take up, while a decrease in EC indicates non-availability of nutrients for plant growth (Van, 1999). EC in an important parameter in managing the fertility status of growing media. The pH of growing media is also vital because it can affect the availability of micro nutrients to plants (Bailey and Bilderback, 1997). The chemical properties which determine suitability of a growing media are primarily pH, cation-exchange-capacity (CEC), and fertility (Miller and Jones, 1995). The CEC is also a measure of a soil or potting media's ability to hold nutrients(Miller and Jones, 1995). The proportion of the macro nutrients in the media (Table 1) shows that the levels of P, K, Ca and Mg are high. This was due to blending of the BX-1 with the fertiliser to sustain the growth of seedlings for a longer time. The percentages of carbon (C) and nitrogen (N) in peat containing growth media were in the range of 40 to 60 % and 0 to 5 %, respectively (Bujang *et al.*, 2011: Huat, 2004), but the C: N ratio was rather high indicating the possibility of immobilisation of N.

The ANOVA result for volumetric water content (VWC) showed that there was no significant difference ($p<0.05$) between the treatments for each week but the weeks differed significantly from one another (Figure 2). The chart shows a decreasing trend of water content in media BX-1 throughout the week. As the plant grew, it used more water making the media contain less water. Plant growth was directly related to soil moisture content (Hagan, 1955). As the rate of growth increased the water became less in the growing medium. This result showed that the amount of water given every day (45 mL) was enough but ought to be increased if the growing period of the crop is longer than 4 weeks.

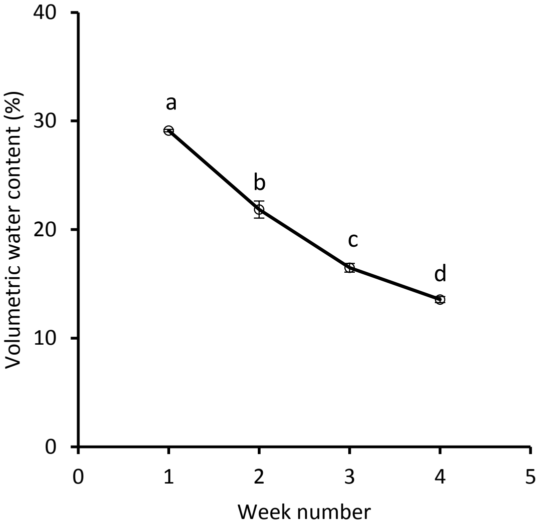

Figure 2: Volumetric water content vs weeks of treatments

Table 2 shows that the significant difference ($p<0.05$) between the treatments in terms of total fresh weight, total dry weight, root dry weight and total leaf area occurred in week 4. For the total fresh weight, Table 2 shows that WCK differed significantly from SRP and DRP irrigation systems in recording the highest total fresh weight of 60.85g as compared with SPR (43.70g) and DRP (49.94 g) on average. SPR recorded the lowest total fresh weight probably due to lower water use efficiency of the system and high water loss. The better growth in the WCK treatment was due to the highest uptake of plant nutrients N, P, and K in this treatment. Capillary wick irrigation compared with overhead irrigation reduced cumulative irrigation volume by 86% without sacrificing plant growth (Bryant and Yeager, 2002). Overhead sprinklers for small containers are extremely non-uniform in watering (Beeson and Yeager, 2003).

TABLE 2

Treatments interaction for plant growth parameters (weeks)

Week	Treatments	Total fresh weight	Total dry weight	Root dry weight	Total leaf area
		g plant^{-1}			cm^2 plant^{-1}
1	SPR	1.44a	0.31a	0.04a	20.47a
	DRP	1.44a	0.31a	0.04a	20.47a
	WCK	1.44a	0.31a	0.04a	20.47a
2	SPR	10.70a	0.97a	0.22a	129.04a
	DRP	8.61a	0.79a	0.16a	101.1a
	WCK	8.71a	0.70a	0.16a	96.95a
3	SPR	30.78a	2.45a	0.72a	292.83a
	DRP	28.37a	2.29a	0.63a	298.63a
	WCK	33.87a	2.68a	0.76a	311.15a
4	SPR	43.70b	4.04b	1.38b	349.81b
	DRP	49.94b	4.76b	1.49b	430.64a
	WCK	60.85a	7.07a	3.05a	440.25a

SPR = Overhead sprinkler, DRP=Drip, WCK=Capillary wick irrigation system.

For the same week and plant parameters, means (n=3) followed by the same letter are not significantly different at 5% significant level.

WCK gave the highest total dry weight (7.07 g) and root dry weight (3.05 g) (Figure 3a and 3b), which differed significantly ($p<0.05$) from SPR and DRP. There were no significant differences between SPR and DRP in terms of total dry weight and root dry weight. Water plays an important role in dry matter accumulation, because the nutrients have to be in solution before they can be taken up by the roots; this could be the reason why WCK had the highest total dry weight.

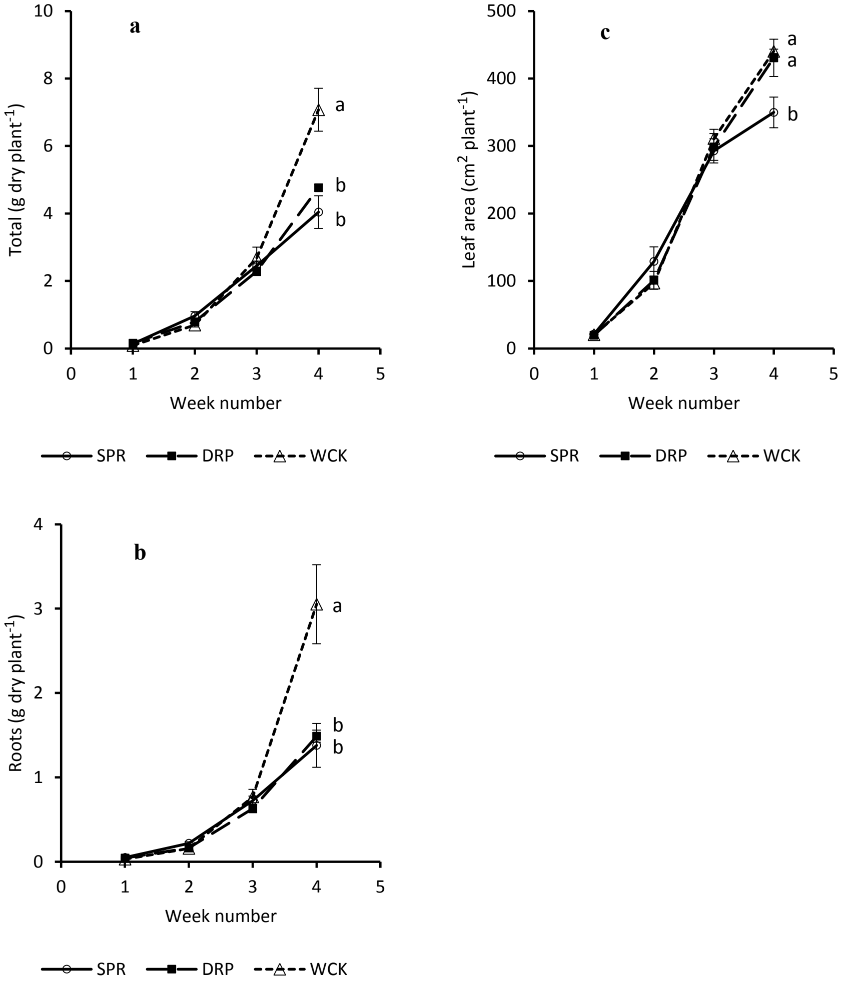

Figure 3: Treatments according to weeks interaction for (a). Total Dry Weight (b) Root Dry Weight (c) Total Leaf Area. SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system

The mineral nutrients of P and N exerted pronounced influence on photosynthate and dry matter partitioning between root and shoots (Costa *et al.*, 2002). Increased root growth contributes to root biomass and root dry weight under higher atmospheric CO_2 regardless of species or study conditions (Rogers *et al.,* 1994; 1996).

Leaf area is also a function of water content of plants. From Figure 3c, it can be seen that the treatments differed significantly in total leaf area and this was seen in week 4. There was no significant (p>0.05) difference between WCK and DRP treatments but they differed from SPR treatment significantly (p≤0.05). This was because WCK and DRP irrigation systems used more water compared to the

SPR irrigation system, which is the worst of the three systems studied. SPR had about 90% water loss (900 mL out of 1000 mL) during application due to wind and canopy interception which led to the system appying more water outside the container compared to the two water saving systems (DRP and WCK) where water loss occurred only by leaching and evaporation.

Table 3 shows the tissue analysis of water spinach under three irrigation systems. ANOVA found significant interaction between weeks and treatment in terms of N, P, and K contents in the plant tissue but no significant difference in Mg and Ca content between the treatments at 5% level.

TABLE 3
Interaction between treatment and weeks for tissue analysis of N, P and K.

Week	Treatments	N	P	K
		g plant^{-1}		
1	SPR	3.29a	0.50a	2.44a
	DRP	3.86a	0.47a	2.7a
	WCK	4.2a	0.52a	3.14a
2	SPR	3.95a	0.57a	2.83a
	DRP	4.00a	0.57a	2.69a
	WCK	3.51a	0.45a	2.03a
3	SPR	3.03a	0.44a	1.74b
	DRP	3.46a	0.44a	2.29a
	WCK	3.48a	0.49a	2.3a
4	SPR	2.9b	0.42a	1.9a
	DRP	2.6b	0.35b	1.53b
	WCK	3.55a	0.48a	2.25a

SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system.
For the same week and nutrient content, means (n=3) followed by the same letter are not significantly different at 5% level.

Despite not been significant between treatments (for Ca and Mg), the Ca content of the plant tissue increased from week 1 to week 4 (Figure 4a) while Mg content was highest in the first week and lowest in the fourth week (Figure 4b). This could be due to the availability of the nutrients in the growing media (BX-1). There were no sign of deficiency for all the nutrients thoughout the experiment.

For the N, P and K nutrient contents, ANOVA showed significant (p<0.05) difference in interaction between weeks and treatments (Table 3). From Figure 5, it can be seen that higher N, P and K nutrient contents were recorded in treatment 3 (WCK). In the WCK irrigation system, the media was kept saturated throughout the experiment and the water was applied slowly and steadily to the plant, making

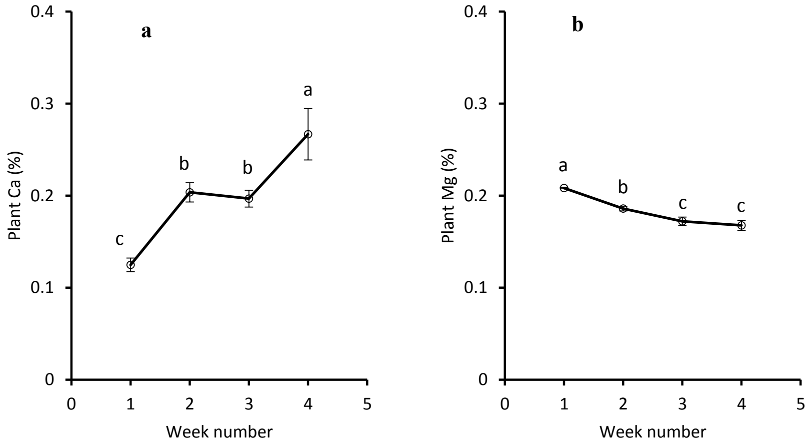

Figure 4: Trend (in weeks) of (a) Ca content of water spinach and (b) Mg content of water spinach.

available the three elements for plant uptake. When plants are N-deficient, relatively more photosynthate is used by roots as they develop greater length to aid the plant in obtaining more N (Barber, 1995).

Irrigation methods influence the water-absorption pattern and several other factors which have an effect on plant growth (Argo and Biernbaum, 1994; Ku and Hershey, 1991; Molitor, 1990). For maximum water conservation, the capillary wick system should be used (Bainbridge, 2001). The lower nutrient content obtained in SPR and DRP was due to the higher amount of leachate observed in the systems. Westervet (2003) noted that lack of uniformity in SPR irrigation means that more water is needed to irrigate all the plants which leads to over- or under-watering of some plants. It is difficult to uniformly irrigate a crop without over- or under-watering some plants (Lienth, 1996).

Table 4 shows a significant difference in the amount of leachate collected at the end of the experiment between the treatments. The highest amount of leachate was recorded in DRP which does not differ significantly(p>0.05) with SPR but does differ significantly (p<0.05) with the WCK irrigation system (Figure 6). In the WCK irrigation system, there was no leachate in weeks 3 and 4 as the plant used up all the water. Despite the absence of leachate in the WCK system, the plants did not experience water stress and in fact produced more biomass compared to other treatments.

Table 4 also shows that WCK had the lowest cumulative N, P, K, Ca, and Mg nutrients leachate contents, differing significantly with SRP and WCK and DRP (Figure 7a to 7e).

SPR and DRP did not differ statistically in recording the highest amount of cumulative N leachate while the WCK gave the lowest amount of cumulative N leachate at 201.79 mg L^{-1} (Figure 7a). Leaching occurs when inorganic forms of N, particularly nitrite (NO_2^-) and nitrate (NO_3^-) are solubilised and carried with water through the soil profile or with surface waters (Hodges, 2010). Nitrogen concentration in each treatment was related to the volume of water leached out by RB 900 tube. Zotarelli *et al*., (2009) also noted the same trend of nitrate leaching as water percolated, resulting in the amount of nitrogen loss decreasing over time.

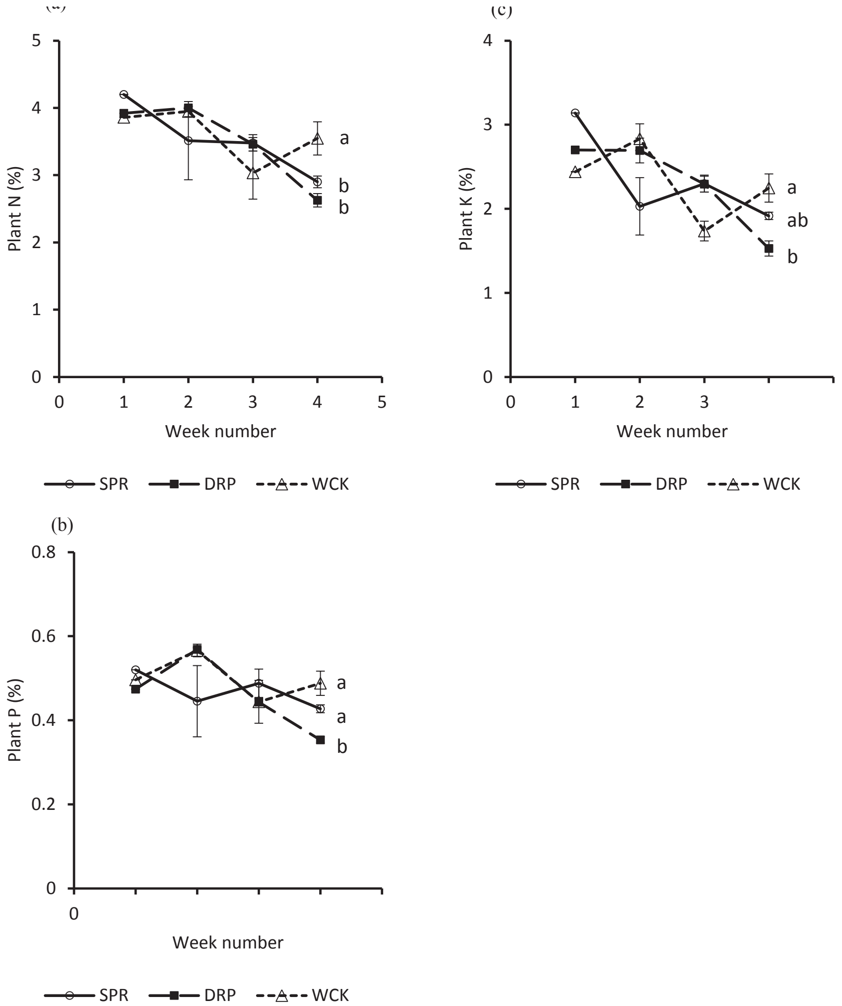

Figure 5: Interaction between treatments and weeks for (a) N tissue content in water spinach (b) P tissue content in water spinach (c) K tissue content in water spinach. SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system

TABLE 4
Overall cumulative means for nutrients content and volume of leachate.

Week	Treatment	Parameters					
		N	P	K	Ca	Mg	Volume
				mg L^{-1}			ml
1	SPR	143.23a	90.08a	251.45a	13.48a	22.05a	183.93a
	DRP	133.083a	84.08a	123.03a	13.31a	20.48a	182.83a
	WCK	144.66a	90.58a	216.85a	13.71a	22.35a	182.97a
2	SPR	204.35a	153.23a	563.33a	28.86a	45.9a	304.75a
	DRP	205.76a	149.36a	166.21b	16.17a	22.81b	290.28a
	WCK	201.79a	152.06a	264.00b	17.70a	25.87b	292.60a
3	SPR	232.53a	191.91a	710.64a	40.72a	63.95a	379.58a
	DRP	234.58a	184.11a	333.56b	28.44b	42.69b	393.50a
	WCK	201.79b	152.06b	264.00b	17.70c	25.87c	292.60b
4	SPR	246.34a	201.56a	779.45a	43.18a	67.57a	474.03a
	DRP	245.09a	208.00a	357.54b	29.48b	44.72b	549.06a
	WCK	201.79b	152.06b	264.00b	17.70c	25.87c	292.60b

Notes: SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system
Column Means (n=3) for the same week and same parameter followed by the same letter are not significantly different at 5% level.

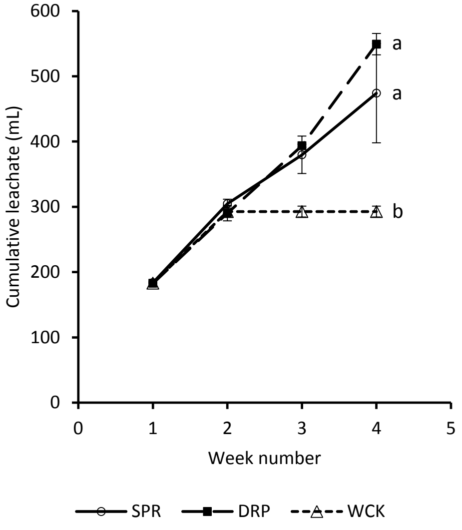

Figure 6: Overall cumulative means of leachate for the treatments in 4 weeks.
SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system

The WCK cumulative leachate for P differed significantly ($p \leq 0.05$) from SPR and DPR (Figure 7b) but there was no difference ($p > 0.05$) between SPR and DRP. From Figure 7c, it is noted that the highest cumulative means for K leachate was obtained in SPR, which differs (p<0.05) from WCK and DRP irrigation systems. Among the treatments, WCK showed the lowest in cumulative means for leachate of P, recording only 33.8% of the SPR potassium leachate. There was no increase in N, P, K, Ca and Mg leachate in WCK after week 2 as there was no leachate in the treatment. The amount of P removed in the BX-1 media by different irrigation system was very low compared with other nutrients measured. As P is an immobile element, its amount in the leachate is expected to be less. Phosphorous content in runoff increased after fertilisation (Renou *et al.*, 2000). As the WCK system produced a lesser amount of leachate, naturally the amount of P was also less. Substantial amounts of the total available K in peat soil is always present in soil solution. Hence, K is strongly mobile and prone to leaching. In addition, K fixation is almost absent in peat soil sand despite its high cation exchange capacity, peat soils do not readily adsorb exchangeable K (Andrisse, 1988). As shown in this experiment, a higher amount of K leachate was recorded compared to the other nutrient elements.

From Figure 7d and 7e, it can be seen that the highest cumulative means for Ca and Mg were obtained from the leachate in the SPR irrigation system (43.17 and 67.5 mg L^{-1}), which differs significantly (p<0.05) from DRP (29.47 and 44.72 mg L^{-1}) and WCK (17.69 and 25.82 mg L^{-1}). The lowest was obtained in the WCK system because there was no leachate after week 2. Calcium and Mg are mostly cations that can be leached from most soils. Considerable amounts of Mg can be leached from sandy soils especially after application of fertilisers (Havlin *et al.*, 1999).

Figure 8 shows cumulative water use and water use efficiency (WUE) of the three irrigation systems.. The WCK system gave the highest cumulative water use which differed significantly (p>0.05) from SPR and DRP irrigation systems, but between SPR and DRP there was no difference (p<0.05). WCK consumed the most amount of water which explains why it produced the highest plant growth. Nonetheless, there was no difference in water productivity (amount of biomass produced per unit water consumed) between the three treatments (data not shown). The WCK system had the highest water use because water was non-limited, and accumulation of dry matter is dependent not only on nutrients and solar radiation availability but also on water availability.

However, WUE (the amount of water used per unit water applied) for WCK was highest, differing significantly (p<0.05) from other treatments, while the lowest was obtained in the SPR system (Figure 8b). There was a huge amount of water loss in the SPR treatment, where water wastage was more than 90%. The WCK system recorded the highest water use efficiency recorded because of the way water was applied and taken up by the plants. The system supplied what the plants needed exactly, with little wastage. WUE is among the most important indices for determining optimal water management practices (Kharrou *et al.*, 2011). Increasing the efficiency of water use by crops is of vast concern because of the increasing demand for water, yet the desired effects are barely achieved (Hatfield *et al.*, 2001).

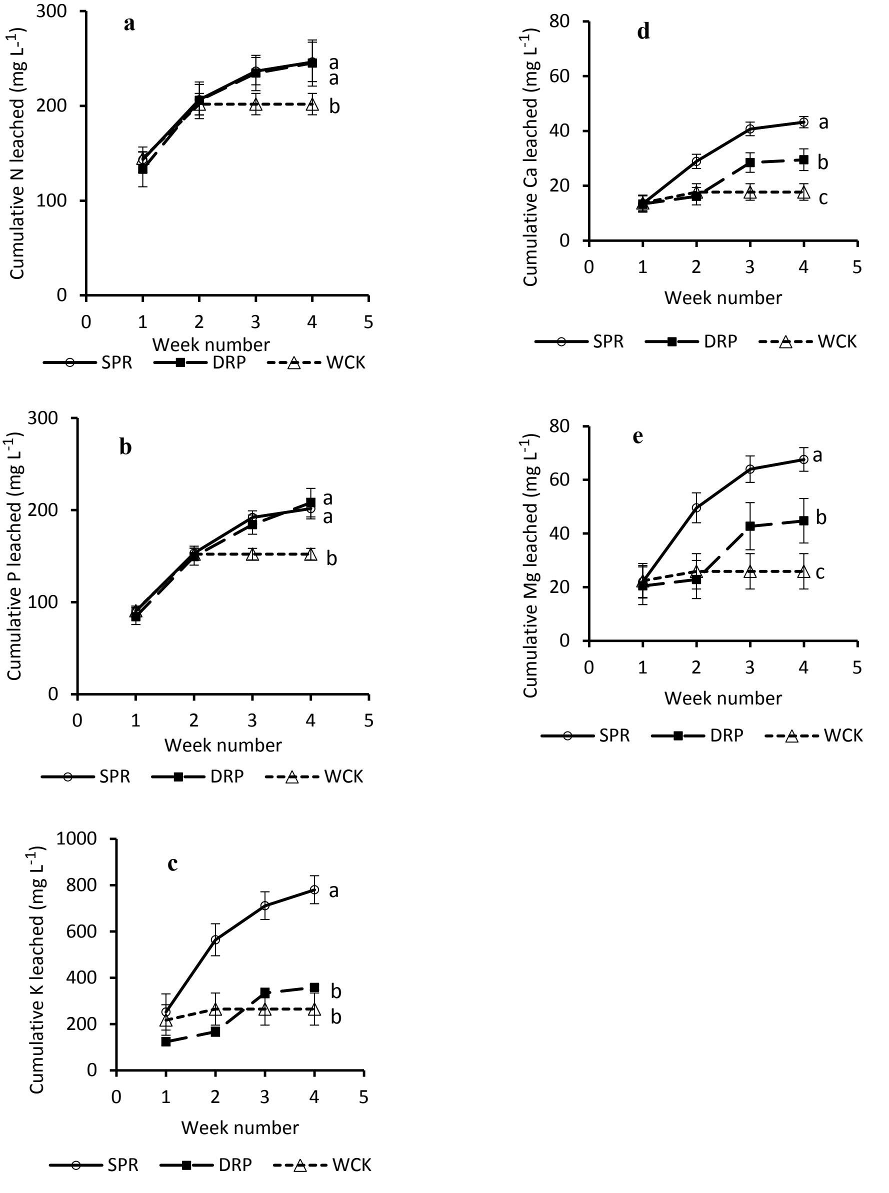

Figure 7: (a) Cumulative N leached by different water treatments (b) P leachate content by treatments in weeks (c) K leachate content by treatments in weeks (d) Ca leachate content by treatments in weeks (e) Mg leachate content by treatments in weeks. SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system.

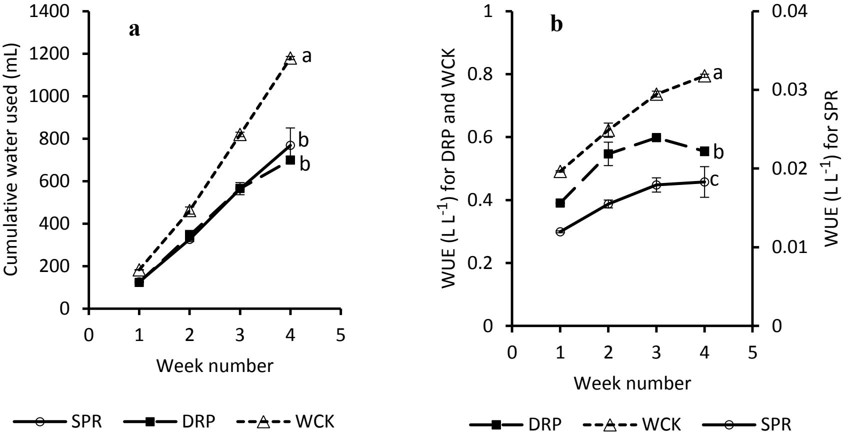

Figure 8: (a) Cumulative water use of water spinach under three irrigation system (b) Water use efficiency of water spinach under three irrigation system. SPR= Overhead sprinkler, DRP= Drip, WCK= Capillary wick irrigation system

CONCLUSIONS

Physical and chemical analysis carried out on the BX-1 media showed that it can store large amounts water but available water content to the plant might be low depending on the growing plant. The pH was 5.54 which is within the desired range of most growing media and suitable for many plant species. BX-1 is considered as non-saline with an EC of 0.9 dS m^{-1}. Total carbon and total nitrogen were 41.48 % and 1.41%, respectively. The nutrients of P, K, Ca and Mg in the BX-1 media were 0.32 %, 0.66 %, 1.02 % and 0.35%, respectively. This shows a high nutrient content and this was due to the addition of slow releasing fertilisers and lime to make the media more suitable for seedling production. It can be concluded that the best irrigation system for the use in RB-900 tube was the WCK irrigation system. The WCK system gave the highest growth for roots by dry weight and leaf area. This was because the WCK treatment had the lowest amount of leachate and nutrient losses, so it had the highest nutrient content in the plant for N, P, and K. WCK also had the highest water use efficiency, but there was no difference in water productivity between the three irigation system. WCK consumed the highest amount of water (but had least water wastage) to produce the highest amount of roots biomass and leaf area compared to drip and overhead sprinkler treatments.

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