Green Roof: Vegetation Response towards Lead and Potassium

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ABSTRACT
Implementation of green roof in Malaysia as an alternative in stormwater management is considered rare. It is due to this facility is not included the Malaysian's Stormwater Management Manual namely the Urban Stormwater Management Manual of Malaysia (MSMA) 1st and 2nd version. The manual is promoting the implementation of SUDS facilities whether as a single facility or integrated ones which is a combination of two or more SUDS facilities. Thus the objectives of this paper are to share the preliminary study of intensive green roof tested under high intensity rainfall (159mm/hr) using rainfall simulator and four intensive green roof test bed with different vegetations. Three species selected for each test bed namely *Axonopus compressus* (*A.compressus)*, *Arachis pintoi* (*A.pintoi*) and *Kalanchoe pinnata* (*K.pinnata).* Another test bed is to leave in without vegetation as a control unit. Results show that all vegetation are not capable in reducing concentration of lead and potassium. In term of quantity control, all test beds showed reduction percentage of runoff hydrograph in the range of 16% to 67%.

KEYWORDS
Green Roof, Heavy metals, vegetation, stormwater management, urban runoff, pollutograph

INTRODUCTION
Rapid development in Malaysia has changed the hydrological cycle of the developing or developed area. It is due to the surface changing from pervious to the impervious area that contribute increasing of runoff volume and velocity. Thus, developed area are no longer can response to the previous storm annual recurrence interval (ARI) and normally reduce the capability of the area to response the rainfall events. Affect from this scenario can be seen when downstream area receive high volume of stormwater consequently occurrence of flash flood. Other than that, debris and suspended solids of stormwater water runoff also play a role as conveyance of pollutants. This will deteriorate the water quality of nearby waterbodies. Water scarcity also become an issue in urban area. Due to these problems, Department of Irrigation and Drainage, Malaysia (DID) launched a new Urban Stormwater Manual of Malaysia (USWM) in 2001 and second edition of USWM was launched in August 2012 by DID as improvement and summarizing the previous manual. This manual introduces the new perception in stormwater management. The integrated approach have been promote where quantity, quality and amenity of stormwater runoff and surrounding catchments area are taken equally into consideration for design the urban drainage system. This integrated approach known as Sustainable Urban Drainage System (SUDS) or Best Management Practices (BMPs). SUDS replace the concept of rapid disposal in conventional method to the new paradigm called control at source. SUDS is mimic nature and typically manages rainfall close to where it falls. The system design to balancing three major items that important in urban development of communities namely water quantity, water quality and amenity. The numbers of facilities are promoting in SUDS like swales, detention storage, wetland, bioretention, green roof and etc. which can be applied in series. However, in USWM, design guideline for green roof as stormwater facilities is not stated.

Many benefits of green roof were recorded by researchers around the globe in every aspects like social, economic and environment. Villareal et al (2004 & 2005), Berndtsson (2010), Getter et al (2007) and VanWoert et al (2005) discovered that benefits not only in attenuation of stormwater

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runoff and improve stormwater quality but also can create new habitat, filter pollution, decrease noise, improve air quality, reduce microclimate and etc. Notable that green roof or vegetated roof has at least 3 layers namely plant level, substrate, and drainage layer. There are two type of green roof known as extensive green roof and intensive green roof. The difference among these types more depends on depth of substrate. Researchers agree that extensive green roof has thinner substrate compare than intensive green roof (Getter & Rowe (2006), Stovin et al, (2012) & Berndtsson, (2010)). Researchers who done study related to the green roof also agreed that intensive green roof can support varies plants type and need intense maintenance (Rowe (2011), Speak et a.l (2013). The most important in plant selection is the intention of green roof design whether it open to public as recreational which is as aesthetic appeal or just for sake of stormwater management. Other than that, environmental conditions, media conditions and depth, installation method and maintenance should be considered. Climate and microclimate in the specific area of green roof also give an impact in plants selection. Air temperature, wind, rainfall distribution throughout the year will determined the suitable species can survive. Thus species that have high survival, drought and stress tolerance become a preference (Getter & Rowe (2006), Greenroofguide.co.uk (2013)). So this paper will discuss the response of selected green roof vegetation in this study towards potassium and lead in order to improve rain water quality before it reach to the ground.

Malaysian Experience

In Malaysia, even there are no design guideline but the application of the green roof system is getting increase. Green roof has receive numerous attention by profesional researchers in Malaysia to study the performance and improvement of green roof for Malaysian weather condition. The study has been done can be grouped into six which are research on stormwater management, environment, materials, plants, energy and building. Recorded by Abdul Rahman et al (2013), Malaysia has 30 green roofs project which are built in various type of buildings. 22 are built as intensive green roof whereas the other are extensive green roof. This may be due to the sentiments of many professionals, that extensive green roof has lower aesthetic value compare to intensive green roof as the plant selection is limited. They concluded that Malaysian professionals in built environment industry are aware of green roof technology. Regarding green roof as best management practices in stormwater management, several studies has been made. All researches finding agree the contribution of the green roof in attenuation of peak discharge. For example, Musa et al (2011) study on green roof in reducing quantity of stormwater runoff. They developed two flat type roof models in a small scale which are vegetated (test) and non-vegetated (control). Results gained that vegetated roof model retained 17% to 48% stormwater runoff from rainfall.

STUDY AREA & METHODOLOGY

Intensive green roof prototype was built in physical laboratory of River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia. Three major steps involve in the study and steps are explained below.

Intensive Green roof testing platforms and plants establishment

Four water proof test beds or roof platforms with dimension of 1m x 1m was constructed at study area (Figure 1a). Three platforms represent different plant species and 1 platform is bare and act as control bed. 30mm PVC pipe will attached on the low end of the beds to direct stormwater runoff or simulated runoff through the measuring device used to quantify runoff and water sampling collection purpose. Every beds will consist of 25mm of drainage cell, cover with filter fabric (geotextile). 50mm clean river sand (diameter 2mm) are put on top and follow with 150mm top soils with coefficient of permeability, k, value is 9.05x10-5cm/s follow by vegetation seeds. The degree of permeability for the top soils is low and it quite important to retain the runoff of rainfall. Seed will sow or spread on it. Base on literature review, species *Kalanchoe pinnata (*Family: Crassulaceae), *Axonopus compressus* (cow grass) (Family: Gramineae) and *Arachis pintoi* (Family: Fabaceae) due to it resistance to insects, weeds and others are planted.

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Rainfall Simulator

A rainfall simulator is constructing to create heavy and light rainfall. A plastic tank 2m x 2m x 1m is support with 2.5m or 3m above a potable desk. The base of the tank is drill with grid holes of 2mm diameter at 48mm intervals. Needles will attach to the base of each hole to create regular drops similar to real rainfall **(**Figure 1b). 159mm/hr of rainfall intensity were use in this study. Example of running experiment show in Figure 2.

Data Collection (Hydrologic and Water Quality)

Runoff discharged from the outlet of the green roof prototype were recorded. Outflow generated from all green roof prototype also collected for water quality analyses.

Figure 1 (a) Intensive Green roof prototype, (b) *K.pinnata*, (c) *A.pintoi*, (d) *A.compressus*

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Figure 2 Simulated rainfall on control test bed.

RESULTS & DISCUSSION

Peak Flow Attenuation

Experiment were conducted to determine the response of studied vegetation in reducing peak flow. To achieve this purpose, rainfall with intensity of 159mm/hr was simulated above the green roof prototype for all vegetation. Result shows that all green roof manage to delay the outflow of the runoff. Figure 3 show details percentage of runoff reduction by each species. *A.compressus* gave a highest percentage in flow reduction in all experiments made except on 27 November 2014. Data recorded show this species manage to attenuate peak flow in the range of 30.5% to 67%. It is believe due to the *A.compressus* has highest density in covering the green roof surface compare to others studied species. *K.pinnata* gave an interesting performance on 27 November 2014 for become highest in flow reduction (59%). It might be happened due to maturity of *K.pinnata* and it also have significantly different in size. Even though the physical of species were not measured but the different among them was visually obvious. Base on the observation during the experiment in the laboratory, this species able to intercept simulated rainfall water before it reach the ground even though the density of the plants is less than *A.compressus*. This is due to this succulent species have wide and big size of leaves. Along the study period, *K.pinnata* gave a response in peak flow reduction in the range of 44.5% to 59% which is promising to be as one of the green roof vegetation in stormwater management. In all simulated rainfall, *A.pintoi* shows lowest capable in peak flow reduction compare to other species and even compare to the control test bed. Lowest value of peak flow reduction by this species was recorded is 16.5% to 46.5.

Lead and Potassium Pollutographs

From the results gained, it clearly show that green roof generated and behave as sink for lead (Pb) and potassium (K). Wastewater that poured into the all prototype contain both metals. After four days of antecedent dry period, simulated rainfall was run above these green roofs. Results show the quality of the outflow consist higher concentration of lead and potassium compare to concentration in wastewater. Higher potassium in all experimented result is believed due to the application of fertilizer in order to growth the vegetation. However significant concentration of lead in outflow water need to study further. Figure 4 show all green roof leached lead except *K.pinnata* on 27 October 2014. Even though several times in study period, wastewater that poured into the green roof as pollutants does not exist any lead, but this metal occurred in outflow of green roofs prototype with significant concentration. Pollutograph shows in Figure 4 prove that discharge from green roof outflow are not significantly affected the concentration of these metals. Other than that, all vegetation studied were not capable in reducing the concentration of potassium and leads.

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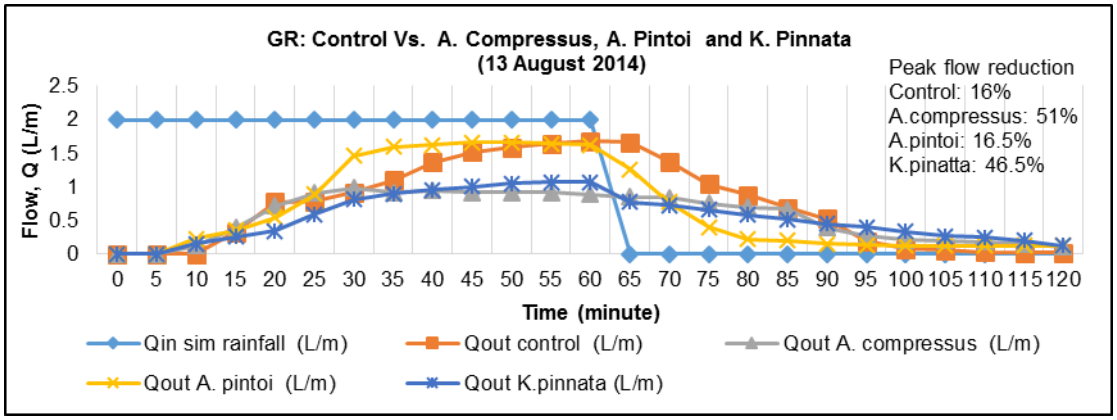

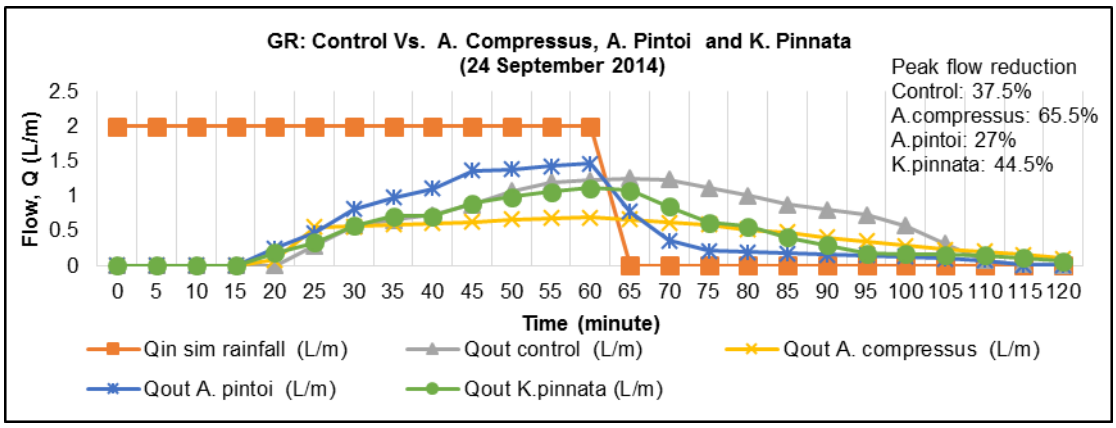

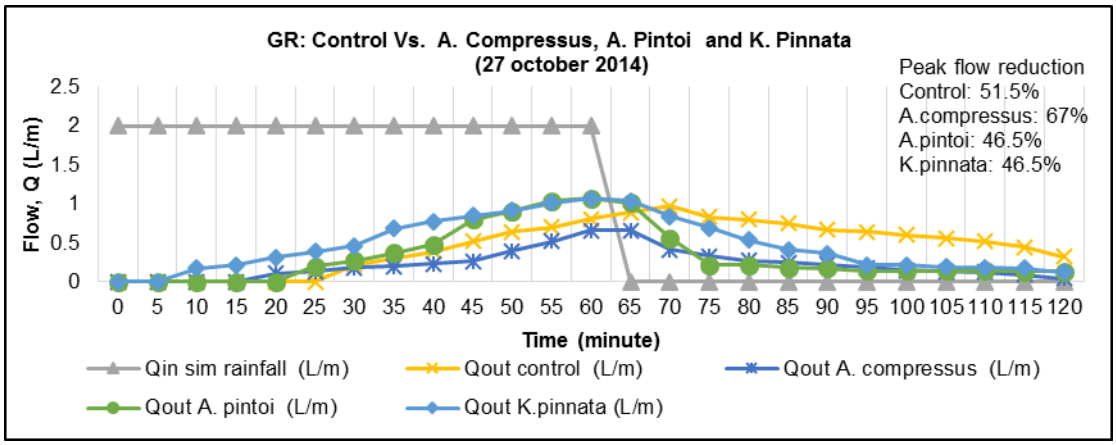

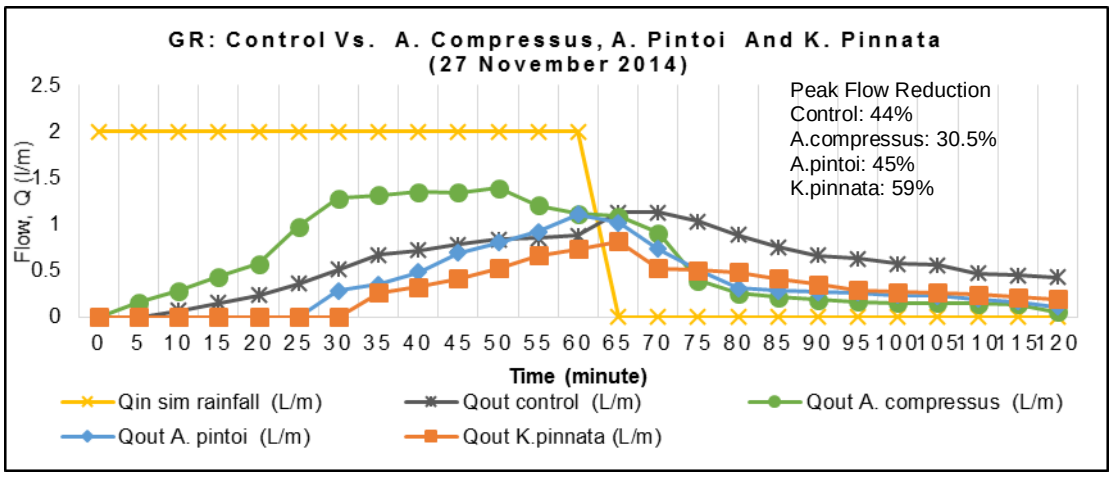

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Figure 3 Runoff reduction by each vegetation species during simulated rainfall

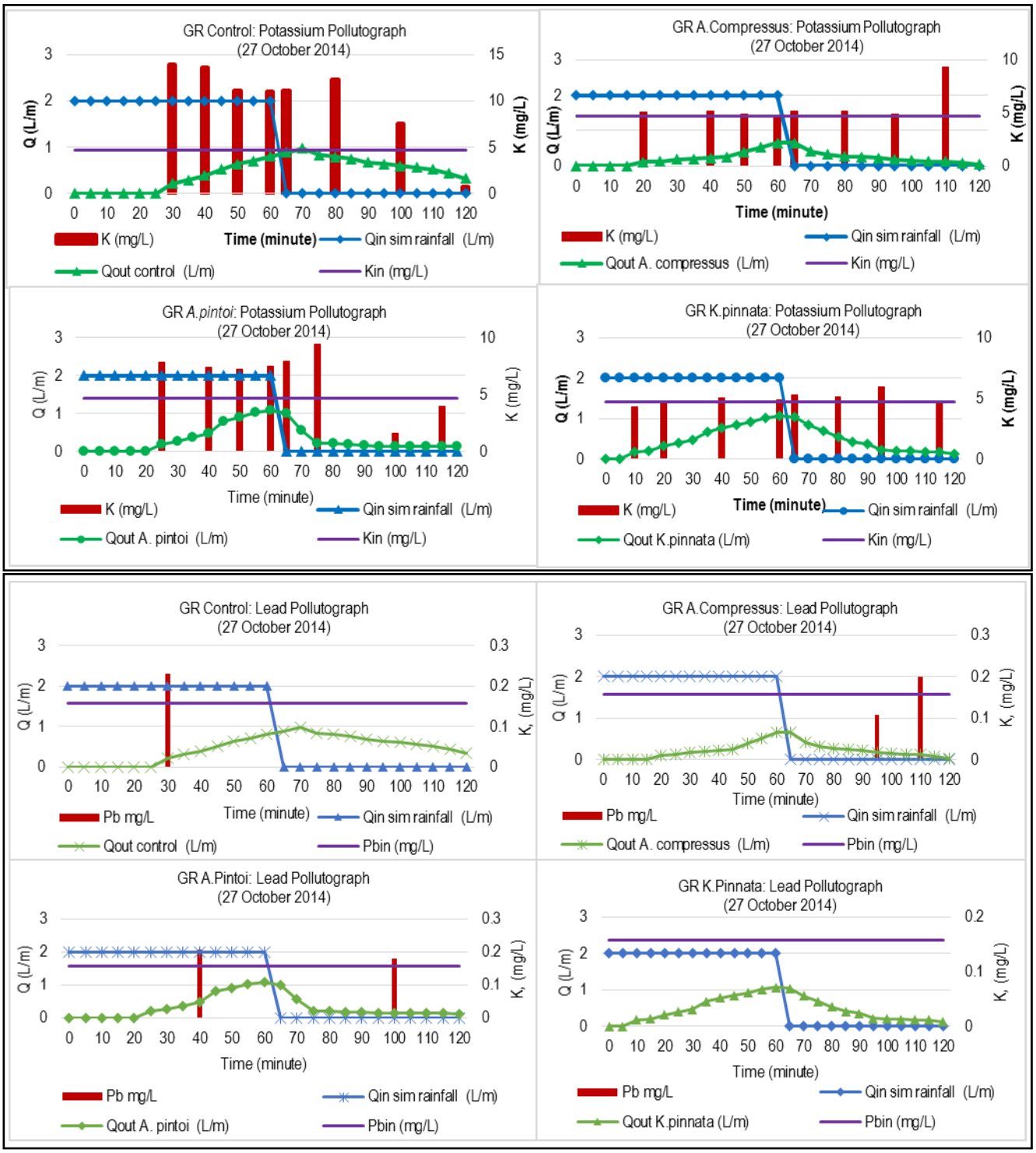

Figure 4 Response of every vegetation species in reducing potassium and lead

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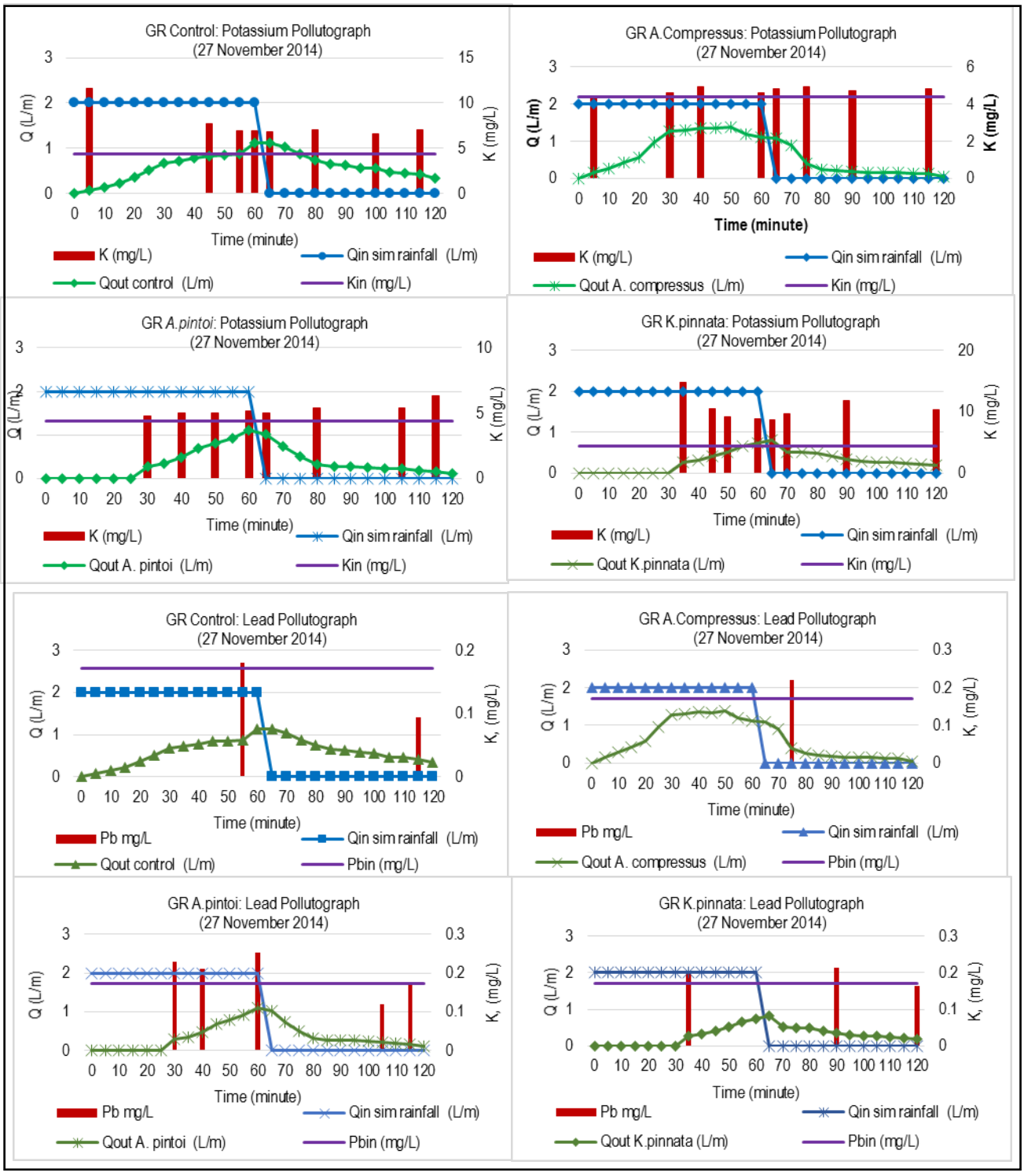

Figure 5 Vegetation response in reducing lead and potassium

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CONCLUSION

Vegetation response to high intensity rainfall is very promising. All species manage to reduce the peak flow. Nevertheless their response towards metals studied were varies. But none of them capable to reduce the concentration of potassium and lead. Even the concentration of both metals in water from green roof exceeded the Malaysian Raw Drinking Water Standard, but the water can be used for domestic like toilet flushing and plant watering.

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