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RESPONSE OF GREEN ROOF SYSTEMS TO COMPOUND PRECIPITATION EXTREMES: A CASE STUDY BRATISLAVA – TRNÁVKA

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INTRODUCTION

The increasing frequency of compound climate extremes, particularly heatwaves and intense rainfall, poses a significant challenge for urban water management. Green roofs represent an effective adaptation measure capable of mitigating such impacts by reducing surface runoff and enhancing the retention capacity of impervious urban areas.

EXPERIMENT

This experiment aimed to analyze the effect of different precipitation event types on the retention performance of green roof systems. Measurements were conducted in the Bratislava–Trnávka locality between 07-10/2025, a period characterized by extreme air temperatures and short, high-intensity rainfall events. Six experimental modules were constructed, varying in substrate depth, additive composition, and storage layer type. Runoff from each module was collected in storage containers, while substrate moisture and temperature were continuously monitored using sensors (Fig. 1).

Fig. 1 *Photo documentation from the experiment*

The experimental setup, specifically the composition of the green roofs into five modules, is shown in Tab. 1. The slope and vegetation were 2%. The main difference is in the substrate, specifically in its depth and in one module biochar is added. A textile drainage-accumulation layer is also tested (module 4).

Tab. 1 *Experimental setup, layer and parameters of green roof modules*

	Modul 1	Modul 2	Modul 3	Modul 4	Modul 5	Modul 6
Roof slope	2%	2%	2%	2%	2%	2%
Vegetation	sedum	sedum	sedum	sedum	sedum	Control modul
Roof substrate	*BTV	*BTV	*BTV	*BTV	*BTV+ 10% biochar	
Substrate depth	7 cm	10 cm	14 cm	10 cm	10 cm	
Drainage layer	Dimpled membrane	Dimpled membrane)	Dimpled membrane)	Water retention mat	Dimpled membrane	

The analyzed period was from July 24 to October 24, 2025, during which the total precipitation and runoff from individual roof modules were measured. The humidity and temperature of the substrate were measured in the modules. During this period, there were 28 days with precipitation (152 hours) (Fig. 2), of which 17 precipitation events were identified and evaluated (Tab. 2).

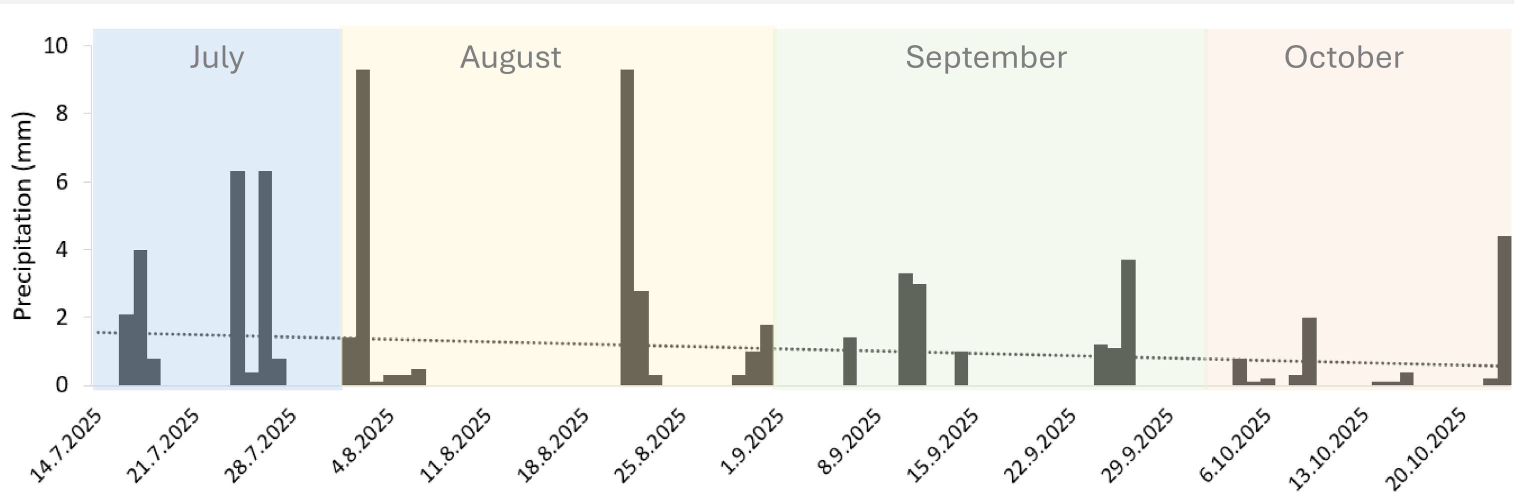
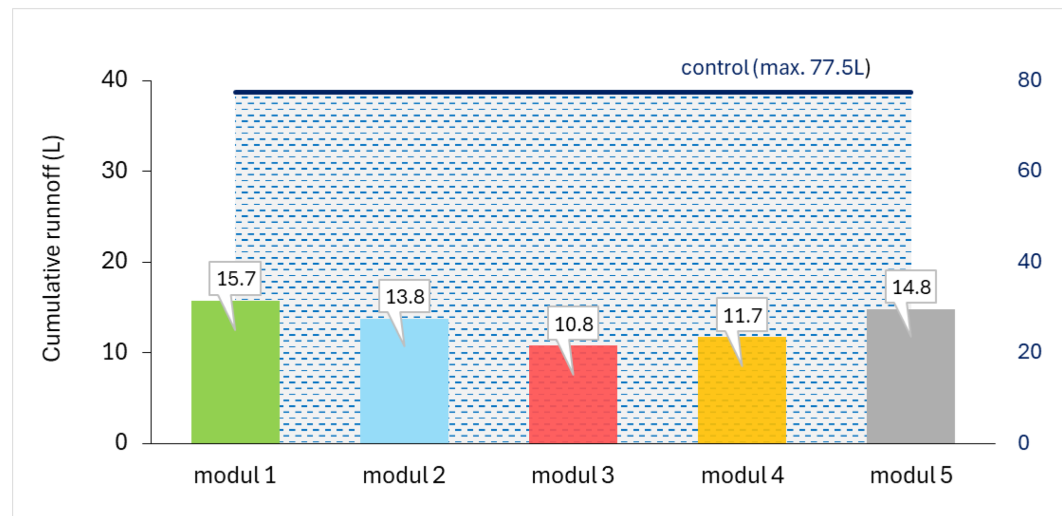


Fig. 2 *Hourly precipitation data (period 14.7. - 24.10.2025)*

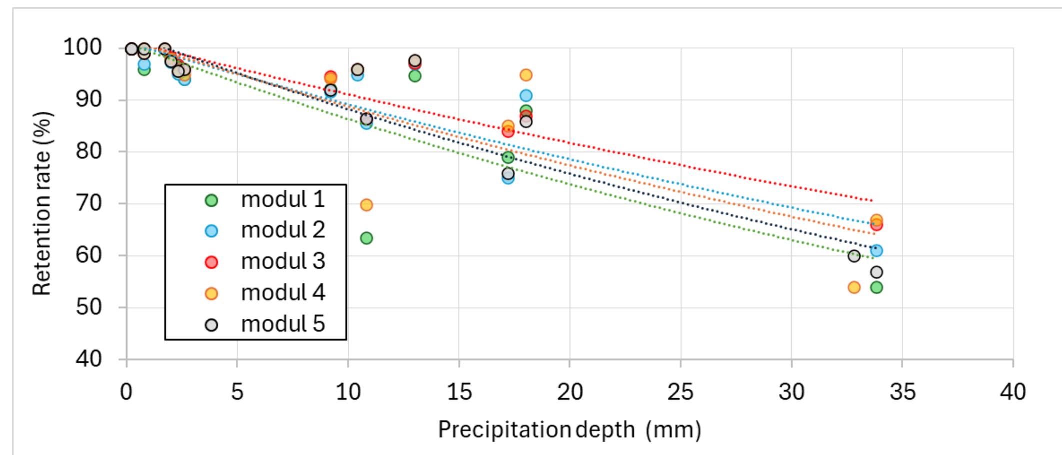
RESULTS

The results demonstrated that short, high-intensity rainfall events produced significantly higher runoff compared to longer, low-intensity precipitation. Retention performance was not strongly influenced by substrate type and storage layer design. These findings highlight the importance of considering precipitation extremes and compound climate events in the design and implementation of green roof systems as an effective urban climate adaptation strategy.



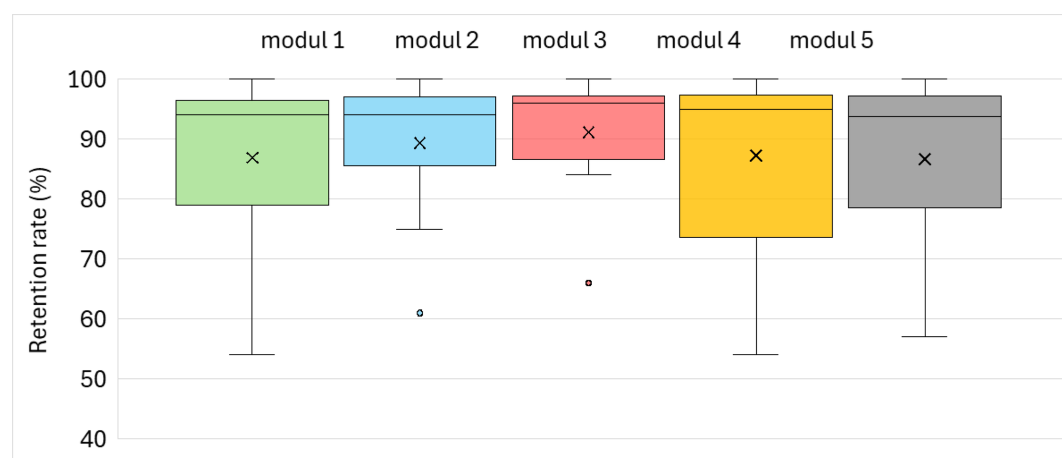
A) Figure 3 presents the cumulative runoff values over the monitoring period.
The differences between the columns allow comparison of the water retention capacity of individual modules.

Fig. 3 *The cumulative runoff values*



B) Figure 4 shows the relation between total rainfall and retention efficiency for individual modules. The exponential trendline indicates that retention efficiency generally decreases with increasing rainfall.

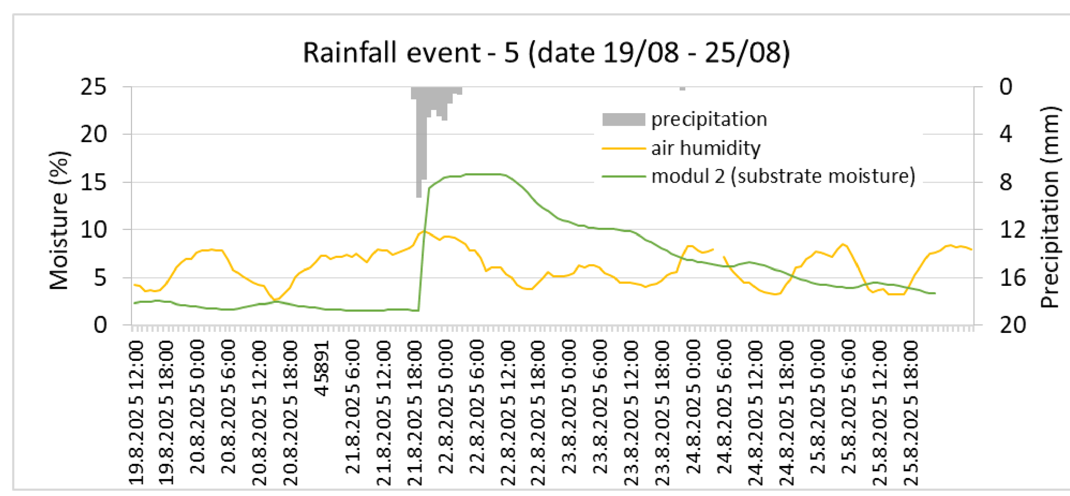
Fig. 4 *Retention efficiency in relation to total rainfall*



C) The box plot (Fig. 5) shows the distribution of retention efficiency for each module. Differences in medians and variability indicate the effect of substrate depth and composition on retention capacity.

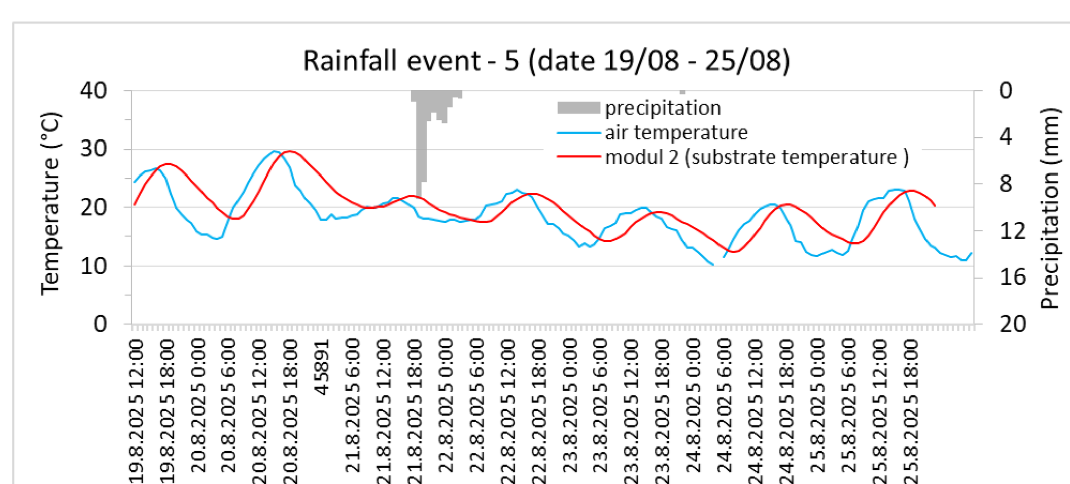
Fig. 5 *Retention efficiency box plot for experimental modules*

In the next step, each rainfall event should be analyzed individually, considering multiple characteristics such as intensity, duration, and initial substrate moisture.



D) The graph shows the variation of substrate moisture and air humidity during a selected rainfall event, highlighting the relationship between atmospheric conditions and substrate response.

Fig. 6 *Change in substrate moisture during a rainfall event (33.8 mm)*



E) Figure 7 compares the daily temperature cycle of the substrate and air, showing their correlation and the buffering effect of the substrate on rainfall.

Fig. 7 *Daily temperature regime of substrate during rainfall event (33.8 mm)*

Tab. 2 *Experimental setup, layer and parameters of green roof modules*

Event	Date	Total rainfall (mm)	Event	Date	Total rainfall (mm)	Event	Date	Total rainfall (mm)
1	24. - 27.07.	32.8	7	30. - 31.8.	10.4	13	05.10.	1.7
2	01. - 02.08.	17.2	8	06.09.	0.8	14	09.10.	2
3	04.08.	0.2	9	10. - 11.09.	18	15	10.10.	2.3
4	06.08.	0.2	10	14.09.	2.6	16	23.10.	0,8
5	21. - 22.08.	33.8	11	24. - 25.09.	9.2	17	10.24.	13
6	23.08.	0.2	12	25. - 26.09.	10.8			

CONCLUSION

These results represent the first data from measurements that provide insight into the response of green roofs to their layer composition. Based on the short monitoring period, a higher substrate depth retained more rainwater, and the biochar content in the substrate only slightly increased the retention potential. The importance of the drainage-accumulation layer, which plays a crucial role in moisture changes following dry and rainy periods, was also confirmed.

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