Engineering Hydroponic Systems for Sustainable Wastewater Treatment and Plant Growth

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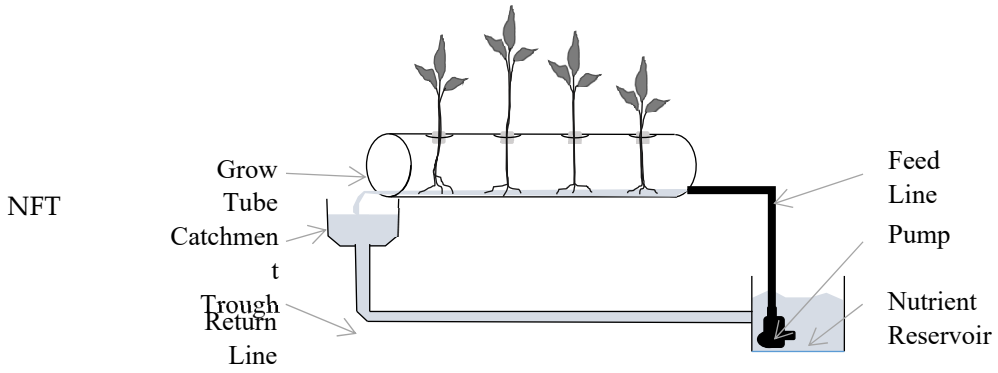

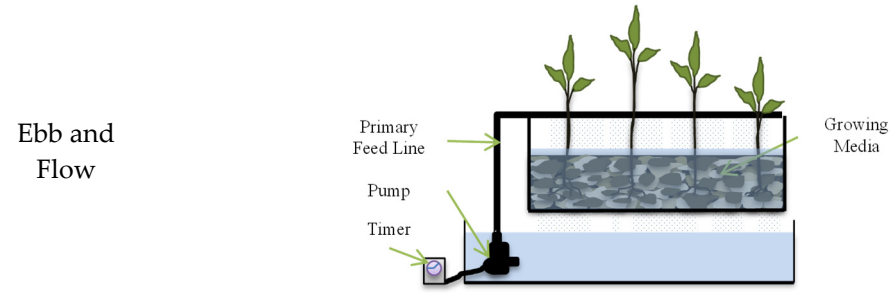

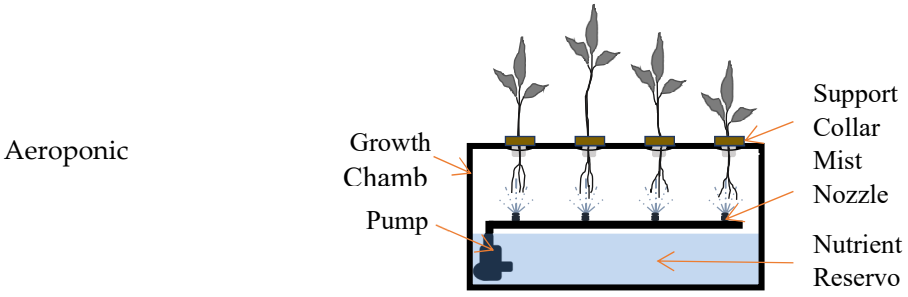

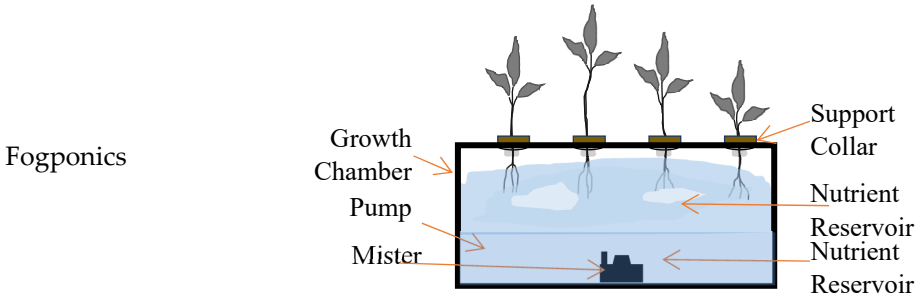

Figure S1 Diagrams of different hydroponic systems, NFT, DFT, Aeroponic and Fogponics.

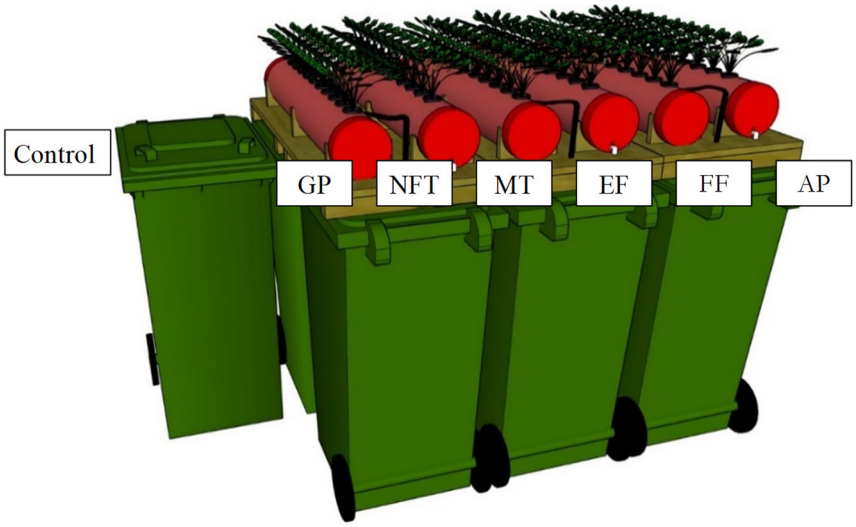

Figure S2 An illustration of the complete setup and the location of the different systems.

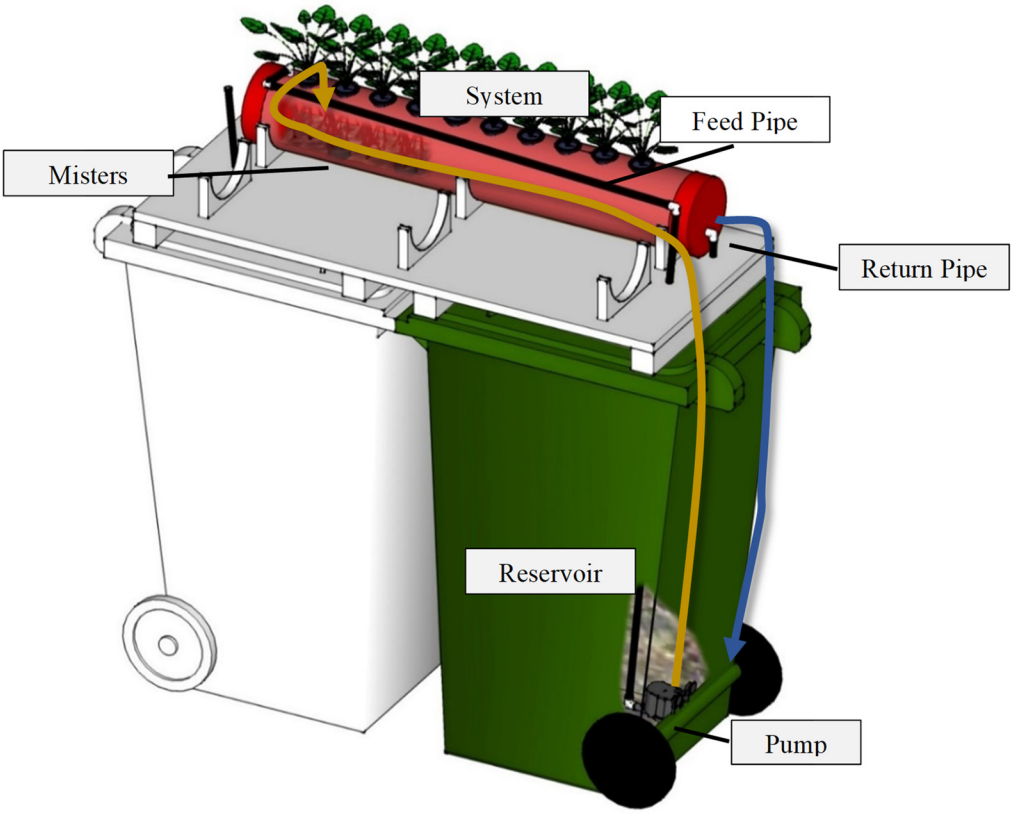

Figure S3 An illustration of the proposed setup. The system that is grey is removed for illustrative purposes so the system in colour can be seen. The pipe is supported by its reservoir (coloured) and that of the opposite system (grey). The pump pushed the water to the far end of the pipe. It

flowed through the system via its specific method (illustrated is the MT system) and returned the other end to the reservoir by the return pipe.

Figure S4 The six systems with tomato plants - clearly the growth in the fogponic system (MT) and the aeroponic system (AP) have the greatest growth.

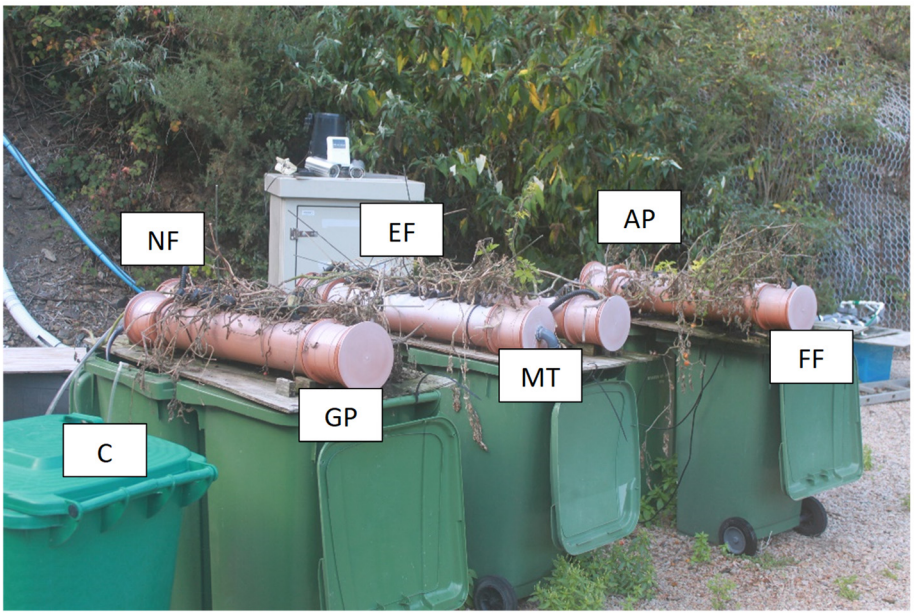

Figure S5 A photo of the experiment at the point when all tomato plants died. It was suspected that this could be caused by high amounts of salts in the sewage seeping in from the sea.

Figure S6 Photo of the outlet of the fogponic system, showing the extent of root growth, restricting the exit flow from the system.

Figure S7 A photograph of the roots of an ivy plant. It can be seen that the roots have been cut creating a log of roots.

Table S1 Average lengths and mass over all the experiments, at the start and end, the percentage change in lengths and the p-value of the t-Test where $p<0.001$ was considered extremely significant.

	Average Length				Average Mass			
	Start	**End**	**Change**		**Start**	**End**	**Change**	**t-Test**
	cm	cm	%	t-Test	g	g	%	
GP	48.47	72.53	33.18	$p \leq 0.001$	29.30	50.07	41.48	$p \leq 0.001$
NFT	48.47	72.53	33.18	$p \leq 0.001$	29.00	62.27	53.43	$p \leq 0.001$
MT	48.33	90.77	46.75	$p \leq 0.001$	34.57	82.03	57.86	$p \leq 0.001$
EF	45.00	62.00	27.42	$p \leq 0.001$	31.40	55.45	43.37	$p \leq 0.001$
FF	47.07	54.00	12.84	$p \leq 0.001$	25.10	36.86	31.90	$p \leq 0.001$
AP	42.87	77.93	45.00	$p \leq 0.001$	29.19	46.85	37.69	$p \leq 0.001$

Table S2. Descriptive results of the pH for all the experiments and all the systems with plants and no plants.

System	Plants Start	Plants End	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants Average	No Plants SD
C	7.34	7.31	7.51	7.51	6.95	7.15	7.09	7.09
GP	7.46	7.29	7.98	7.98	6.90	7.72	7.51	7.51
NFT	7.57	7.43	7.68	7.68	6.95	7.42	7.36	7.36
MT	7.58	7.42	7.67	7.67	6.95	7.28	7.17	7.17
EF	7.51	7.35	7.64	7.64	6.95	6.80	7.00	7.00
FF	7.52	7.42	7.79	7.79	6.95	6.92	7.04	7.04
AP	7.34	7.31	7.74	7.74	6.95	7.55	7.43	7.55

Table S3. Descriptive results of the Conductivity for all the experiments and all the systems with plants and no plants.

System	Plants Start *µS/cm*	Plants End *µS/cm*	Plants Average	Plants SD *µS/cm*	No Plants Start *µS/cm*	No Plants End *µS/cm*	No Plants Average *µS/cm*	No Plants SD *µS/cm*
C	1.43	1.31	1.37	0.06	1.25	1.04	1.14	0.09
GP	1.40	1.25	1.33	0.08	1.21	1.07	1.12	0.10
NFT	1.35	1.21	1.31	0.07	1.18	1.04	1.10	0.08
MT	1.32	1.20	1.28	0.08	1.19	1.06	1.12	0.06
EF	1.30	1.20	1.26	0.06	1.19	1.05	1.13	0.11
FF	1.33	1.22	1.29	0.07	1.20	1.07	1.14	0.07
AP	1.34	1.20	1.30	0.08	1.25	1.04	1.14	0.09

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Table S4 Descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the TDS for all the experiments and all the systems with plants and without plants.

System	Plants Start *mg/L*	Plants End *mg/L*	Plants T-Test	Plants Average *mg/L*	Plants SD *mg/L*	No Plants Start *mg/L*	No Plants End *mg/L*	No Plants T-Test	No Plants Average *mg/L*	No Plants SD *mg/L*
C	928.88	1047.63	0.12	987.78	44.88	841.00	843.00	0.48	844.60	5.07
GP	993.13	1023.63	0.27	989.75	23.79	829.50	795.50	0.07	797.50	25.88
NFT	993.13	1023.63	0.16	989.75	23.79	804.00	773.50	0.14	776.40	24.03
MT	947.25	995.38	0.16	970.40	23.61	777.50	732.50	0.18	749.60	19.31
EF	851.25	980.38	0.15	927.08	52.78	817.00	754.50	0.10	783.80	23.79
FF	915.13	976.13	0.44	950.35	26.09	797.50	746.50	0.09	773.10	20.69
AP	1005.63	998.63	0.46	990.40	11.20	786.00	748.00	0.16	777.80	17.93

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Table S5 Descriptive statistics, and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the Turbidity for all the experiments and all the systems with plants.

System	Plants Start	Plants End	Plants T-Test	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants T-Test	No Plants Average	No Plants SD
	NTU	*NTU*		*NTU*	*NTU*	*NTU*	*NTU*		*NTU*	*NTU*
C	17.90	0.18	$P < 0.001$	5.03	7.41	17.66	0.18	0.15	8.50	7.50
GP	20.91	0.54	$P < 0.001$	7.92	9.35	26.27	0.54	$P \leq 0.05$	19.92	8.41
NFT	17.92	0.52	$P < 0.001$	6.86	8.04	23.39	0.52	0.17	15.08	11.29
MT	10.91	0.30	$P < 0.001$	4.77	4.91	43.46	0.30	0.19	29.00	31.76
EF	10.93	0.51	$P < 0.001$	5.87	6.26	16.93	0.51	0.07	13.15	10.33
FF	18.42	0.60	$P < 0.001$	6.43	7.53	21.00	0.60	$P \leq 0.05$	18.59	12.82
AP	16.80	0.62	$P < 0.001$	6.76	7.47	18.60	0.62	0.15	10.99	8.07

Table S6 Descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the TSS for all the experiments and all the systems with plants and without plants and without plants.

System	Plants Start	Plants End	Plants T-Test	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants T-Test	No Plants Average	No Plants SD
	mg/L	*mg/L*		*mg/L*	*mg/L*	*mg/L*	*mg/L*		*mg/L*	*mg/L*
C	38.28	0.34	$p \leq 0.001$	8.87	16.59	23.02	0.11	$p \leq 0.05$	7.00	9.51
GP	37.70	0.32	$p \leq 0.001$	10.99	16.22	47.76	0.06	$p \leq 0.05$	17.64	18.24
NFT	37.70	0.32	$p \leq 0.001$	10.99	16.22	29.37	0.06	$p \leq 0.05$	12.34	12.22
MT	34.32	0.25	$p \leq 0.001$	9.84	14.72	52.15	0.06	$p \leq 0.05$	21.27	24.52
EF	32.49	0.34	$p \leq 0.001$	10.11	14.24	39.87	0.07	$p \leq 0.05$	11.14	16.59
FF	40.11	0.41	$p \leq 0.001$	11.25	17.12	36.78	0.08	$p \leq 0.05$	14.97	19.01
AP	38.53	0.38	$p \leq 0.001$	10.73	16.46	23.09	0.09	$p \leq 0.05$	8.81	9.87

Table S7. Descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the TOC for all the experiments and all the systems with plants.

System	Plants Start	Plants End	Plants T-Test	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants Average	No Plants SD
	mg/L	*mg/L*		*mg/L*		*mg/L*	*mg/L*	*mg/L*	*mg/L*
C	33.54	32.94	0.10	15.37	9.62	17.46	35.25	20.75	7.34
GP	28.13	13.68	$p \leq 0.05$	10.31	1.86	12.08	13.51	13.20	0.59
NFT	25.51	12.35	$p \leq 0.05$	9.23	0.99	13.07	13.69	12.40	1.12
MT	25.16	9.86	$p \leq 0.05$	9.70	1.91	13.23	12.38	11.49	1.71
EF	33.22	13.99	$p \leq 0.05$	11.18	1.74	11.78	16.70	13.63	1.84
FF	32.64	11.92	$p \leq 0.05$	9.42	1.46	12.71	12.59	10.32	1.91
AP	31.47	9.73	$p \leq 0.05$	9.44	1.07	13.49	13.41	11.77	1.74

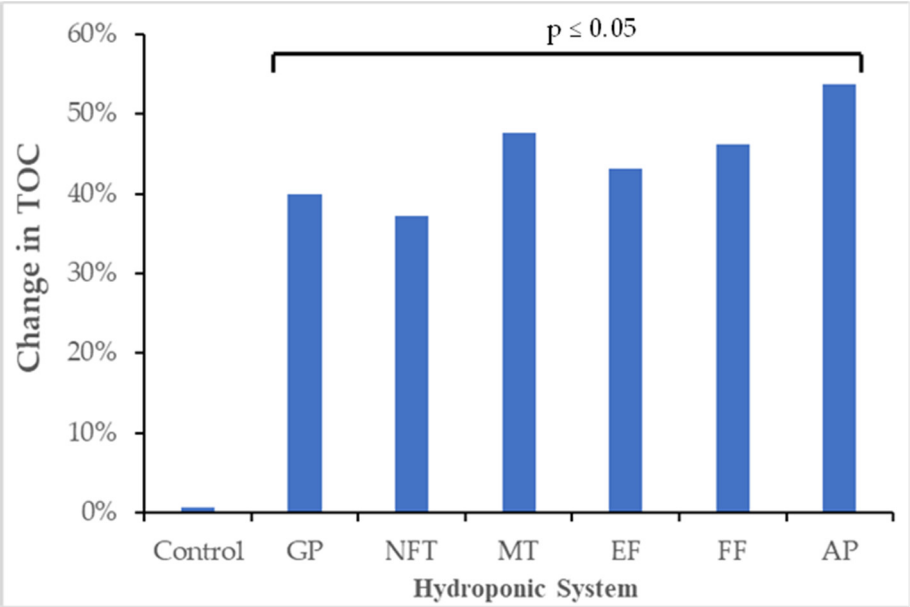

Figure S8. Average reduction of TOC as a percentage change from start to finish overall runs.

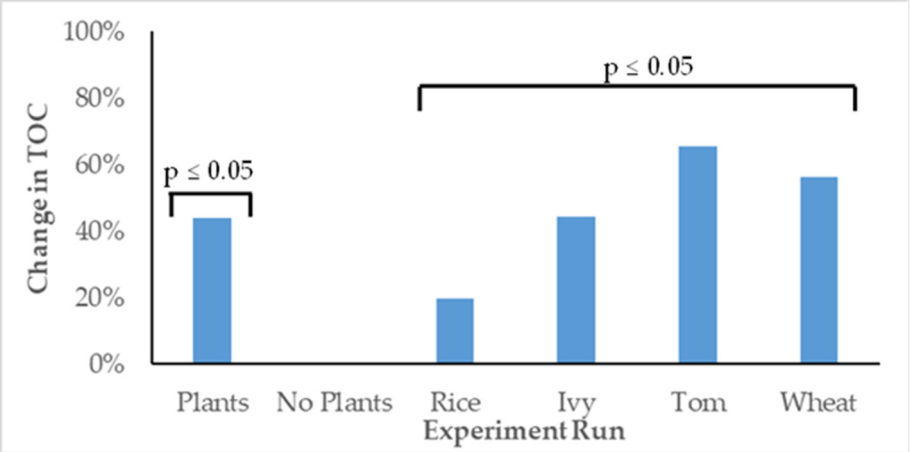

Figure S9. Average reduction of TOC as a percentage change from start to finish of all systems per run.

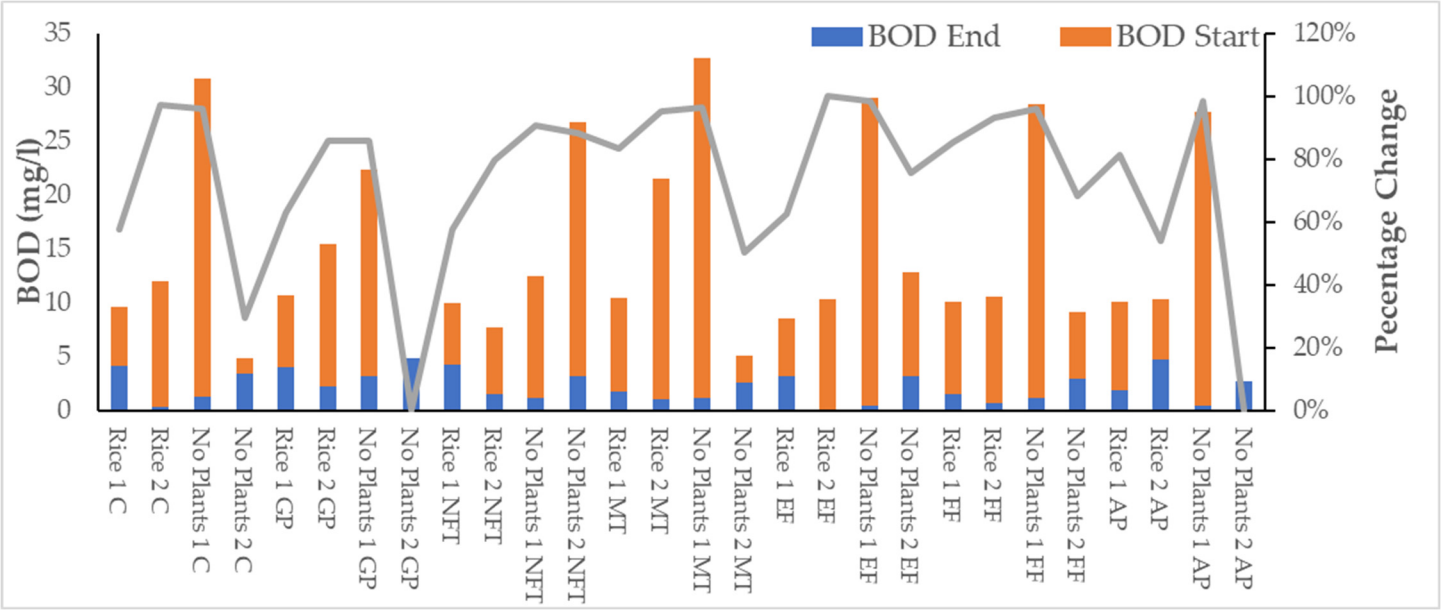

Figure S10 BOD from the beginning of each experiment in red and at the end of the experiment in blue. The percentage change was shown by the grey line.

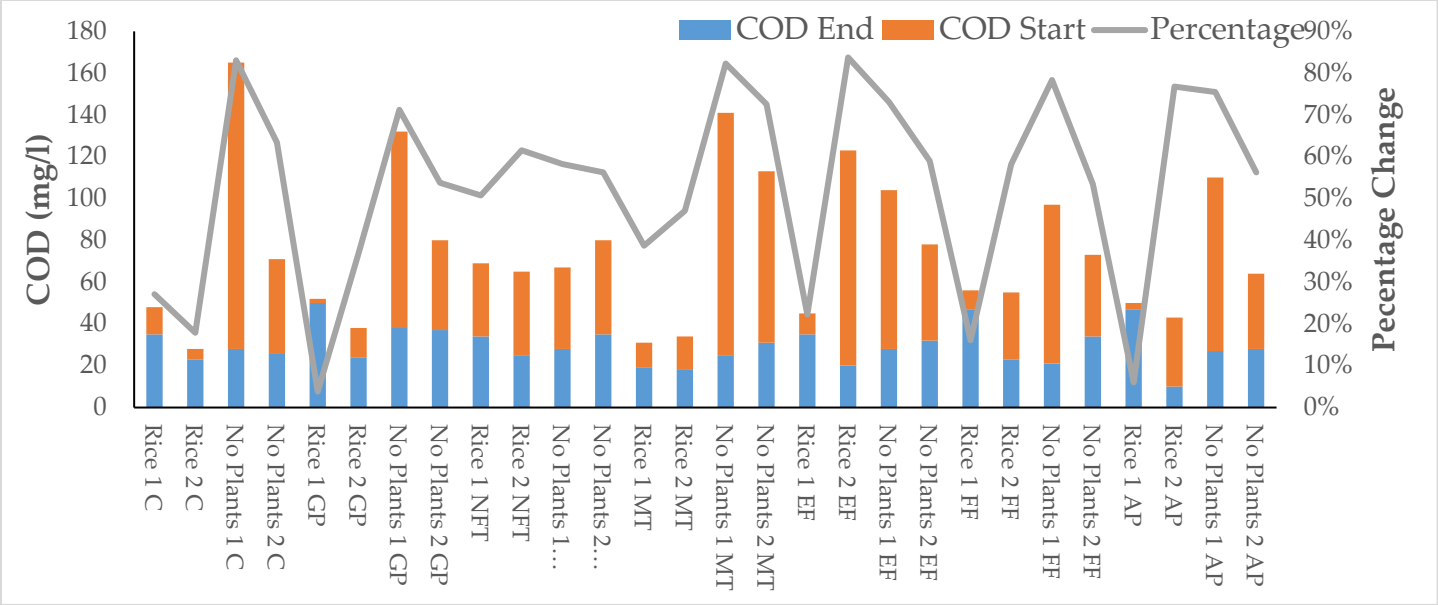

Figure S11. COD from the beginning of each experiment in red and at the end of the experiment in blue. The percentage change was shown by the grey line.

Table S8 Descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the NH_4^+ for all the experiments and all the systems with plants and without plants.

System	Plants Start	Plants End	Plants T-Test	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants T-Test	No Plants Average	No Plants SD
	mg/L	*mg/L*		*mg/L*	*mg/L*	*mg/L*	*mg/L*		*mg/L*	*mg/L*
C	17.05	15.29	0.20	16.38	0.97	10.64	9.88	0.31	10.78	0.88
GP	11.98	0.46	$p \leq 0.05$	4.29	4.65	10.41	9.75	0.08	10.35	0.34
NFT	11.98	0.46	$p \leq 0.05$	4.29	4.65	10.42	10.50	0.46	10.52	0.08
MT	15.89	0.00	$p \leq 0.05$	4.02	6.87	10.91	10.84	0.48	10.78	0.10
EF	13.09	0.00	$p \leq 0.05$	4.18	5.69	10.50	10.58	0.44	10.56	0.04
FF	16.87	0.00	$p \leq 0.05$	4.85	7.14	10.87	10.87	0.50	10.94	0.28
AP	15.38	0.00	$p \leq 0.05$	3.83	6.65	10.75	9.91	0.19	10.48	0.35

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Table S9. Descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the NO_2^- for all the experiments and all the systems with plants and without plants.

System	Plants Start	Plants End	Plants T-Test	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants T-Test	No Plants Average	No Plants SD
	mg/L	*mg/L*		*mg/L*	*mg/L*	*mg/L*	*mg/L*		*mg/L*	*mg/L*
C	21.40	22.61	0.24	21.58	0.87	0.00	2.84	0.24	21.58	$p \leq 0.05$
GP	22.87	3.97	0.10	15.29	9.54	0.55	1.27	0.10	15.29	0.25
NFT	22.87	3.97	0.22	15.29	9.54	0.00	0.00	0.22	15.29	1.00
MT	25.92	25.30	0.22	33.90	9.10	0.35	1.21	0.22	33.90	0.25
EF	10.72	11.57	0.38	12.67	1.74	6.12	0.00	0.38	12.67	0.25
FF	7.67	8.33	0.24	8.98	1.03	1.30	1.78	0.24	8.98	0.39
AP	9.33	10.28	0.36	11.03	1.58	4.50	3.57	0.36	11.03	0.35

Table S10 Descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $P \leq 0.001$ extremely significant) of the NO_3^- for all the experiments and all the systems with plants.

System	Plants Start	Plants End	Plants T-Test	Plants Average	Plants SD	No Plants Start	No Plants End	No Plants T-Test	No Plants Average	No Plants SD
	mg/L	*mg/L*		*mg/L*	*mg/L*	*mg/L*	*mg/L*		*mg/L*	*mg/L*
C	31.66	38.31	0.26	36.70	3.21	23.32	16.86	0.25	36.70	3.21
GP	46.30	55.55	0.31	65.18	15.60	44.14	45.40	0.48	65.18	15.60
NFT	46.30	55.55	$p \leq 0.05$	65.18	15.60	39.97	55.92	1.00	65.18	15.60
MT	36.89	72.93	$p \leq 0.05$	65.77	19.51	33.35	42.42	0.18	65.77	19.51
EF	43.18	82.91	$p \leq 0.05$	70.20	19.15	39.51	48.65	0.07	70.20	19.15
FF	45.63	82.27	$p \leq 0.05$	69.64	18.66	26.19	72.71	0.14	69.64	18.66
AP	42.57	93.02	$p \leq 0.05$	70.33	23.19	45.80	34.15	0.34	70.33	23.19

Table S11. Results for Phosphate, descriptive statistics and t-Test ($p \leq 0.05$ significant, $p \leq 0.01$ very significant, $p \leq 0.001$ extremely significant) of the PO_4 for all the experiments and all the systems with plants and without plants.

System	Plants Start *mg/L*	Plants End *mg/L*	Plants T-Test	Plants Average *mg/L*	Plants SD *mg/L*	No Plants Start *mg/L*	No Plants End *mg/L*	No Plants T-Test	No Plants Average *mg/L*	No Plants SD *mg/L*
C	2.69	2.49	0.11	2.59	0.14	6.61	2.43	0.25	3.66	1.67
GP	3.12	2.52	0.15	2.54	0.53	3.96	5.76	0.27	4.42	1.21
NFT	3.12	2.52	0.05	2.54	0.53	4.78	5.89	1.00	5.58	0.76
MT	3.35	3.07	0.05	2.64	0.62	3.45	3.79	0.18	3.71	0.19
EF	2.75	2.73	0.21	2.43	0.30	6.08	2.26	0.07	4.96	2.04
FF	2.91	2.88	0.24	2.64	0.30	5.52	5.02	0.32	4.43	1.27
AP	3.71	3.88	0.36	3.57	0.33	5.50	8.21	0.31	6.46	1.33

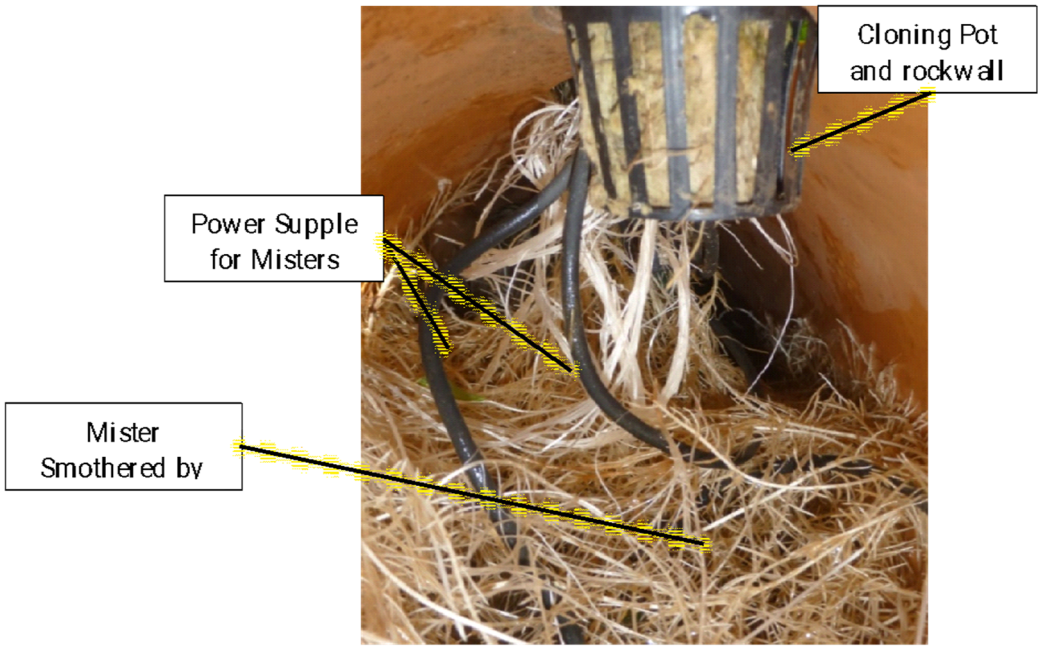

Figure S12 A photograph of the root system within the MT system. It can be seen that due to the excessive root system, the mister was smothered with the roots hindering its functioning.

Figure S13 A photo of the roots in the FF system showing that the roots did not develop to the extent as the roots in the other systems.