

## Final report

To determine and compare the effect of different concentrations of borehole water with and without Aqua4D treatment on turf growth and development

December 2023

STRI Research

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## SUMMARY

The objective of this trial was to assess the effect of different rates of Aqua4D treated borehole water on turf growth and development from germination in pots. Aqua4D-treated borehole water was compared to standard borehole water at 3 different rates.

The benefits of Aqua 4D were only observed when water inputs were low, where water rates were higher the benefits of treating turf with Aqua4D were not observed. This likely means that the optimal benefit of Aqua4D in turf will be under situations where water supplies are restricted. Further study into the use of Aqua4D at lower irrigation rates on amenity turf would be of interest to explore these benefits.

## MATERIALS AND METHODS

- Field site** : One pot trial located in the polytunnel. at STRI research facility in Bingley, West Yorkshire (GPS reference 53.8474 and -1.8579). All pots were constructed with a 90/10 sand/organic matter rootzone and sown with perennial ryegrass.
- Timing** : The trial was initially sown at the end of June 2023 and ran for 18 weeks
- Experimental design** : The trial was laid out as a randomised complete block design. Each treatment was replicated 6 times.

## TREATMENTS

**TABLE 1. Treatment list**

Treatment	Application rate	Volume per pot (ml)
[1] Borehole Water	Full rate	120
[2] Borehole Water	Half rate	60
[3] Borehole Water	Quarter rate	30
[4] Aqua4D treated water	Full rate	120
[5] Aqua4D treated water	Half rate	60
[6] Aqua4D treated water	Quarter rate	30

Treatments were applied 3 times per week after full germination. Treatments were applied daily during germination phase.

Pots were initially sown on 29/06/2023 with further overseeding on 12/07/2023 and 31/07/2023 to ensure a full sward on all pots. Pre-seed fertiliser (ICL Sportsmaster Base 8-12-8) was also added at initial sowing and at 31/07/2023.

Water rate was reduced on 13/07/2023 by 25% to prevent overwatering of pots, initially full rate was 160 ml, half rate 80 ml and quarter rate 40 ml. The reduction in water rate was in alignment with best agronomic practice and to ensure optimum plant health.

## ASSESSMENTS

### **Seed Germination and Establishment**

Germination and subsequent establishment were scored on a 1-10 scale. Assessments were conducted 3 times per week for 2 weeks after seeding.

### **Turf quality**

Turf was assessed visually for turf quality (1-10 scale where 1 = dead turf, 5 = acceptable turf and 10 = perfect turf) (SOP RS0013). After two weeks of sowing, turf quality was assessed weekly during the trial.

### **Visual turf colour**

Turf was assessed visually for colour (1-10 scale where 1 = straw coloured turf and 10 = dark green turf) (SOP RS0014). After two weeks of sowing, turf colour was assessed weekly during the trial.

### **Turf Density**

Turf was assessed visually as a percentage (%) of live grass cover (SOP RS0017). After two weeks of sowing, turf density was assessed weekly during the trial.

### **Turf Uniformity**

Each sampling area or turf sample was assessed on a 1-10 scale (where a score of 1 represented very poor uniformity and a score of 10 signified excellent uniformity such as might be expected in the highest grades of turf) (SOP RS0015). After two weeks of sowing, turf uniformity was assessed weekly during the trial.

### **Root biomass**

Root biomass was assessed as a destructive harvest. Shoot material and rootzone were removed and roots washed and weighed (SOP RS0155). Assessments took place once at the end of the trial.

### **Soil Physics testing**

Water release characteristics were calculated on two samples, half rate borehole water, and half rate Aqua4D treated borehole water.

## RESULTS

### Seed Germination and Establishment

No significant differences were observed in seed germination and establishment (table 2).

### Turf quality

Significant differences in turf quality were observed on 13 of 15 assessment dates (table 3). On 12 assessments borehole water at quarter rate (T3) was significantly lower than all higher water rates (T1, T2, T4, T5). On 5 assessment dates, Aqua4D treated water at quarter rate (T6) had significantly improved turf quality when compared to borehole water at quarter rate (T3).

### Visual turf colour

Significant differences in visual turf colour were observed on 14 of 15 assessment dates (table 4). On 12 assessment dates, pots treated with borehole water at quarter rate (T3) had significantly lighter turf colour than pots watered at higher rates (T1, T2, T4, T5). Additionally, on 11 assessment dates, pots treated with Aqua4D at quarter rate (T6) had significantly darker turf colour than borehole water at quarter rate (T3).

### Turf Density

Significant difference in turf density were observed on 12 of 15 assessment dates (table 5). On 10 assessment dates, pots treated with borehole water at quarter rate (T3) had significantly lower turf density than pots watered at higher rates (T1, T2, T4, T5). On 2 assessment dates pots treated with Aqua4D at full rate (T4) had significantly higher turf density than pots treated with borehole water at full rate (T1). On 1 assessment date, pots treated with Aqua4D at quarter rate (T6) had significantly denser turf than pots treated with borehole water at quarter rate (T3).

### Turf Uniformity

Significant differences in turf uniformity were observed on 14 of 15 assessment dates (table 6). During the early stages of the trial, values fluctuated and differences were inconsistent. Pots treated with full rate of irrigation (T1 & T4) regularly improved turf uniformity over pots with lower irrigation levels (T2, 3, 5 & 6). As the trial progressed, pots treated with Aqua4D at quarter rate (T6) improved turf uniformity when compared to pots treated with borehole water at quarter rate (T3) from 28/09/2023 to the end of the trial period (03/11/2023).

### Root biomass

Significant differences in root biomass were observed in this trial (table 7). Pots treated with full rate of irrigation (T1 and T4) had significantly higher root biomass than pots treated with quarter rate irrigation (T3 and T6).

### Soil Physics testing

Aqua4D treated water at half rate (T5) demonstrated a slight increase in moisture retention over borehole water at half rate (T2) (figures 1 & 2). Capillary porosity was greater at all tensions with Aquad4D (T5) than with borehole water (T2).

**TABLE 2. Seed Germination (1-10)**

Treatment	17/07/23	19/07/23	25/07/23
[1] Borehole Water Full Rate	1.9	2.2	4.8
[2] Borehole Water Half Rate	2.5	2.8	5.6
[3] Borehole Water Quarter Rate	2.5	2.8	6.6
[4] Aqua4D Full Rate	4.2	4.3	6.0
[5] Aqua4D Half Rate	2.7	2.8	6.2
[6] Aqua4D Quarter Rate	3.5	3.7	6.5
P	NS	NS	NS
LSD	-	-	-
d.f.	25	25	25
%c.v.	50.2	44.7	24.5

NS – not statistically significant

**TABLE 3. Turf quality (1-10)**

Treatment	28/07/23	04/08/23	11/08/23	18/08/23	25/08/23	01/09/23	08/09/23	15/09/23	22/09/23	28/09/23	06/10/23	13/10/23	20/10/23	27/10/23	03/11/23
[1] Borehole Water Full Rate	5.6 d	4.8 b	5.3	5.3	5.9 c	5.8 d	5.8 d	5.6 b	5.8 b	5.9 c	6.0 bc	5.6 c	6.1 c	6.3 b	6.0 b
[2] Borehole Water Half Rate	5.1 bcd	4.4 b	4.9	4.9	5.3 b	5.3 cd	5.3 cd	5.1 b	5.1 b	5.0 b	5.0 b	5.0 bc	5.3 bc	5.8 b	5.8 b
[3] Borehole Water Quarter Rate	4.6 ab	3.5 a	4.9	4.9	3.4 a	3.0 a	3.0 a	2.9 a	2.9 a	2.8 a	3.0 a	2.8 a	3.0 a	3.3 a	3.3 a
[4] Aqua4D Full Rate	5.2 cd	4.8 b	5.3	5.3	5.6 bc	5.4 cd	5.4 cd	5.4 b	5.8 b	5.8 bc	6.1 c	5.6 c	5.6 bc	5.6 b	5.3 b
[5] Aqua4D Half Rate	4.7 abc	4.6 b	5.4	5.4	5.3 bc	4.9 c	4.9 c	5.2 b	5.3 b	5.3 bc	5.8 bc	5.6 c	5.5 bc	5.8 b	5.7 b
[6] Aqua4D Quarter Rate	4.3 a	3.3 a	4.8	4.8	3.5 a	4.0 b	3.9 b	3.3 a	3.7 a	3.6 a	3.9 a	4.0 ab	4.6 b	5.5 b	5.7 b
P	<0.001	<0.001	NS	NS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.028
LSD	0.52	0.75	-	-	0.66	0.85	0.84	0.70	0.90	0.89	1.01	1.17	1.25	1.45	1.72
d.f.	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
%c.v.	9.0	14.8	11.2	11.2	11.5	15.1	14.9	13.0	15.9	15.8	17.1	20.7	20.9	22.6	27.2

NS – not statistically significant

**TABLE 4. Turf colour (1-10)**

Treatment	28/07/23	04/08/23	11/08/23	18/08/23	25/08/23	01/09/23	08/09/23	15/09/23	22/09/23	28/09/23	06/10/23	13/10/23	20/10/23	27/10/23	03/11/23
[1] Borehole Water Full Rate	6.0	4.3 ab	5.8 bc	5.8 bc	5.9 c	5.9 c	5.9 c	5.5 c	5.3 b	5.8 bc	5.3 b	5.3 b	5.8 b	6.2 b	5.9 bc
[2] Borehole Water Half Rate	6.0	3.9 ab	4.9 a	4.9 a	5.2 b	5.1 b	5.1 b	4.8 bc	5.0 b	5.0 b	4.8 b	4.8 b	5.2 b	5.9 b	5.8 bc
[3] Borehole Water Quarter Rate	6.0	3.8 a	5.3 ab	5.3 ab	4.1 a	4.0 a	4.0 a	3.5 a	3.4 a	3.4 a	3.6 a	3.2 a	3.4 a	4.3 a	4.1 a
[4] Aqua4D Full Rate	6.0	5.2 c	6.3 c	6.3 c	6.1 c	5.8 c	5.8 c	4.9 bc	5.5 b	5.9 c	5.3 b	4.9 b	5.2 b	5.5 ab	5.2 ab
[5] Aqua4D Half Rate	6.0	4.4 b	5.1 a	5.1 a	5.2 b	5.3 bc	5.3 bc	4.9 bc	5.5 b	5.5 bc	5.3 b	5.3 b	5.5 b	5.6 b	5.8 bc
[6] Aqua4D Quarter Rate	6.0	3.8 a	4.7 a	4.7 a	4.9 b	5.1 b	5.1 b	4.7 b	5.1 b	5.1 bc	5.3 b	5.5 b	5.8 b	6.8 b	6.8 c
P	*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.002	0.003	0.017	0.038
LSD	*	0.63	0.68	0.68	0.70	0.75	0.75	0.69	0.84	0.89	0.92	1.08	1.18	1.32	1.55
d.f.	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
%c.v.	0.0	12.6	10.7	10.7	11.3	12.1	12.1	12.3	14.1	14.6	15.8	18.7	19.4	19.4	23.4

\* - insufficient variation for statistical analysis



**TABLE 5. Turf Density (1-10)**

Treatment	28/07/23	04/08/23	11/08/23	18/08/23	25/08/23	01/09/23	08/09/23	15/09/23	22/09/23	28/09/23	06/10/23	13/10/23	20/10/23	27/10/23	03/11/23
[1] Borehole Water Full Rate	5.5	5.5	6.3 ab	6.3 ab	6.6 b	7.0 b	7.0 b	7.1 b	7.4 b	6.4 b	6.8 b	6.2 bc	6.8 c	7.2 b	6.2
[2] Borehole Water Half Rate	5.3	5.3	6.6 ab	6.6 ab	6.8 b	6.5 b	6.5 b	6.5 b	6.4 b	5.4 b	5.8 b	6.0 bc	6.2 bc	6.7 b	5.8
[3] Borehole Water Quarter Rate	5.8	5.8	5.8 a	5.8 a	4.2 a	3.5 a	3.5 a	3.5 a	3.4 a	3.0 a	3.6 a	3.3 a	3.4 a	3.6 a	3.8
[4] Aqua4D Full Rate	5.7	5.7	8.1 c	8.1 c	7.5 b	7.6 b	7.6 b	7.3 b	7.8 b	6.5 b	7.1 b	6.4 c	6.6 c	6.8 b	5.2
[5] Aqua4D Half Rate	5.8	5.8	7.5 bc	7.5 bc	7.3 b	7.3 b	7.3 b	7.3 b	7.3 b	6.2 b	6.6 b	6.3 c	6.3 bc	6.8 b	5.8
[6] Aqua4D Quarter Rate	5.4	5.4	5.5 a	5.5 a	4.8 a	4.5 a	4.5 a	4.3 a	4.7 a	3.7 a	4.3 a	4.5 ab	4.8 ab	5.7 b	5.6
P	NS	NS	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	0.004	NS
LSD	-	-	1.19	1.19	1.09	1.23	1.23	1.36	1.42	1.46	1.52	1.69	1.66	1.82	-
d.f.	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
%c.v.	16.4	16.4	15.0	15.0	14.8	17.0	17.0	19.0	19.4	23.6	22.5	26.2	24.6	25.1	26.1

NS – not statistically significant

**TABLE 6. Turf uniformity (1-10)**

Treatment	28/07/23	04/08/23	11/08/23	18/08/23	25/08/23	01/09/23	08/09/23	15/09/23	22/09/23	28/09/23	06/10/23	13/10/23	20/10/23	27/10/23	03/11/23
[1] Borehole Water Full Rate	3.8	3.6 abc	6.0 bc	6.0 bc	6.4 c	6.3 c	6.3 c	6.0 d	5.7 c	6.8 c	7.0 d	6.7 c	6.8 c	6.8 b	7.2 b
[2] Borehole Water Half Rate	4.0	3.8 bc	6.5 c	6.5 c	6.3 c	6.3 c	6.3 c	4.0 b	4.5 b	5.4 b	5.3 bc	5.0 b	5.3 b	5.3 b	6.9 b
[3] Borehole Water Quarter Rate	3.3	3.3 ab	5.3 b	5.3 b	3.8 a	3.2 a	3.2 a	2.9 a	2.7 a	3.0 a	3.3 a	3.0 a	3.1 a	3.3 a	3.8 a
[4] Aqua4D Full Rate	3.5	4.1 c	5.5 b	5.5 b	5.2 b	5.3 b	5.3 b	5.0 c	5.9 c	7.0 c	6.6 d	5.9 bc	6.2 bc	5.5 b	6.5 b
[5] Aqua4D Half Rate	3.6	3.8 bc	5.3 b	5.3 b	5.3 b	5.3 bc	5.3 bc	4.0 b	5.6 c	6.8 c	6.2 cd	5.9 bc	5.9 bc	5.6 b	6.8 b
[6] Aqua4D Quarter Rate	3.3	3.0 a	4.0 a	4.0 a	3.5 a	3.2 a	3.2 a	2.5 a	3.5 a	4.6 b	4.6 b	4.8 b	5.0 b	5.5 b	6.1 b
P	NS	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	0.008
LSD	-	0.59	0.91	0.91	0.89	0.99	0.99	0.83	0.94	1.24	1.27	1.33	1.35	1.66	1.82
d.f.	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
%c.v.	17.6	14.0	14.0	14.0	14.7	16.9	16.9	17.2	16.9	18.6	19.5	21.5	21.1	26.3	24.7

NS – not statistically significant

**TABLE 7. Root biomass (g)**

Treatment	20/11/2023
[1] Borehole Water Full Rate	8.9 c
[2] Borehole Water Half Rate	5.8 abc
[3] Borehole Water Quarter Rate	2.9 a
[4] Aqua4D Full Rate	8.8 c
[5] Aqua4D Half Rate	8.4 bc
[6] Aqua4D Quarter Rate	4.8 ab
P	0.015
LSD	3.72
d.f.	15
%c.v.	37.4

## DISCUSSION

The objective of this trial was to assess the effect of different rates of Aqua4D treated borehole water on turf growth and development from germination in pots.

Pots were initially sown on 29/06/2023, with full germination achieved by 27/07/2023. Pots were irrigated daily until full germination was achieved, after which irrigation was applied 3 times a week. During a typical growing season, a football stadium would irrigate at 15-20 mm to maintain a wet soil bed and encourage growth. This would also be applied 2 to 3 times a week to provide a consistent wetting. Equivalent depth of irrigation used in this trial, the full rate was 12 mm (16 mm for the first 2 weeks) of irrigation, 6 mm (8mm for the first 2 weeks) at half rate and 3 mm (4 mm for the first 2 weeks) at quarter rate.

Treatment differences were observed at various points during this trial between borehole water and Aqua4D treated water. However, it was observed from 22/09/23 through to the end of the trial at 03/11/23 that Aqua4D treated water at quarter rate (T6) was not significantly different in turf colour to borehole water at full rate (T1). This trend was also seen in turf uniformity from 28/09/23 through to the end of the trial, and in turf quality on 27/10/23 and 03/11/23. Although not consistent throughout the trial period, this trend may highlight the benefit of the Aqua4D system with low water availability.

Aqua4D treated water at quarter rate (T6) consistently demonstrated significant improvements in turf colour over borehole water at quarter rate (T3) from 25/08/23 through to the end of the trial. The benefits of Aqua 4D were only observed when water inputs were low, where water rates were higher the benefits of treating turf with Aqua4D were not observed. This likely means that the optimal benefit of Aqua4D in turf will be under situations where water supplies are restricted.

Further study with a field trial on a sand based rootzone may be of interest to explore different reduced water rates using the Aqua4D system on the effect of turf health and growth.

## PHOTOGRAPHS

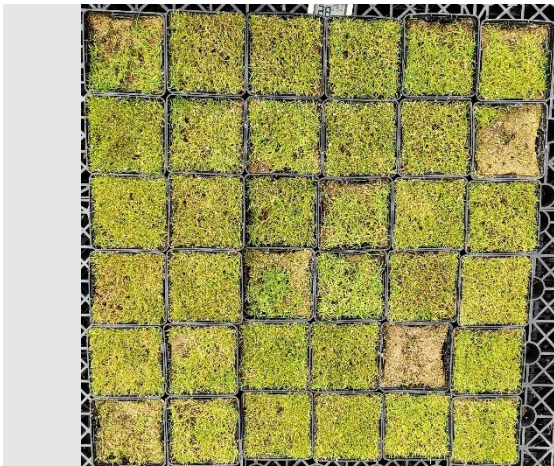


Photo 1: Trial layout 13/10/2023

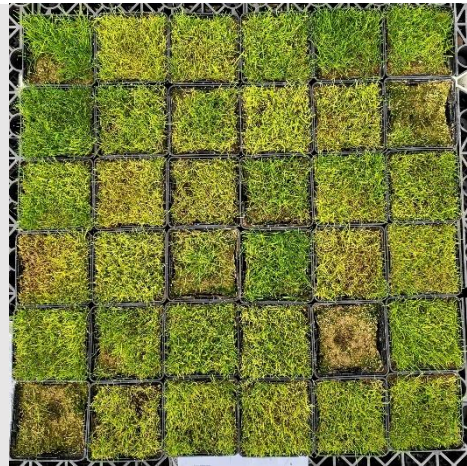


Photo 2: Trial layout 07/11/2023

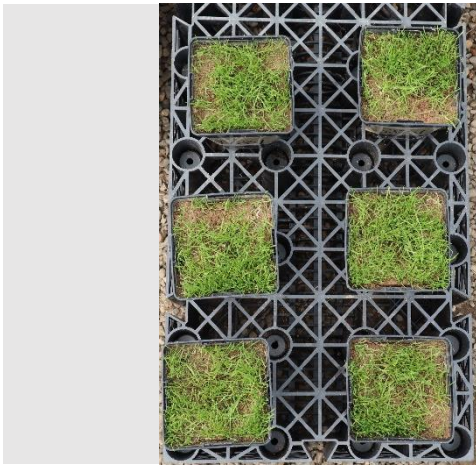


Photo 3: Treatment 1 28/07/2023

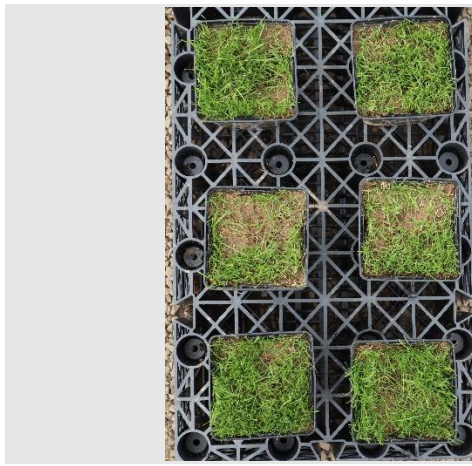


Photo 4: Treatment 2 28/07/2023

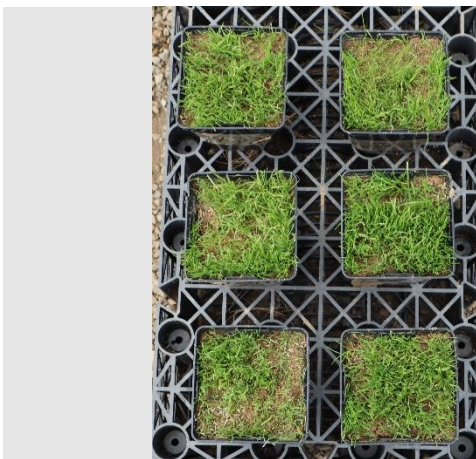


Photo 5: Treatment 3 28/07/23

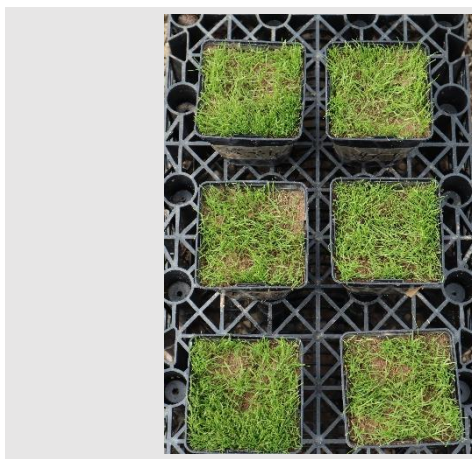


Photo 6: Treatment 4 28/07/23





Photo 7: Treatment 5 28/07/2023

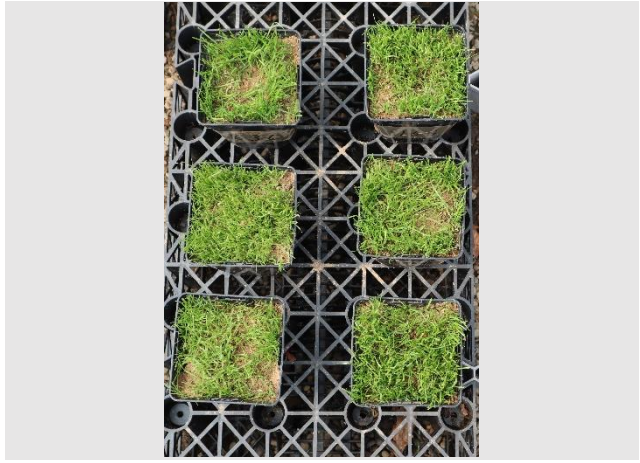


Photo 8: Treatment 6 28/07/2023

Signed:



(Study Director)

Date: 21/12/2023

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## APPENDICES

**FIGURE 1. Water release characteristics of compacted rootzone materials – T2 Borehole Water Half Rate**



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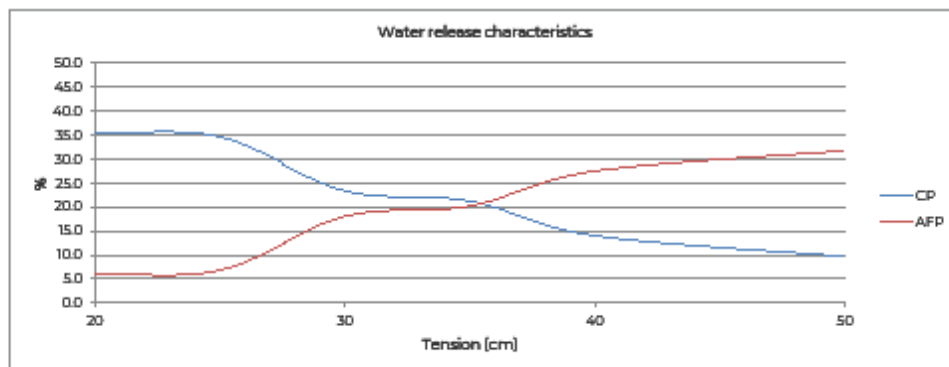
e. [enquiries@strigroup.com](mailto:enquiries@strigroup.com)

[www.strigroup.com](http://www.strigroup.com)

### WATER RELEASE CHARACTERISTICS OF COMPACTED ROOTZONE MATERIALS

CLIENT:	AQUA 4D	RESULTS TO:	OT
		SAMPLE NO:	A20496/1
		DATE RECEIVED:	11/12/23
		DATE REPORTED:	21/12/23
DESCRIPTION:	T2	TEST RESULTS AUTHORIZED BY:	
CONDITION UPON ARRIVAL:	MOIST		Michael Baines, Laboratory Manager

Particle density (g/cc)	2.644	
Bulk density (g/cc)	1.548	
TPS (%)	41.5	
Tension (cm)	CP (%)	AFP (%)
20	35.5	6.0
25	34.6	6.9
30	23.4	18.0
35	21.3	20.2
40	14.0	27.4
50	9.7	31.7



THESE RESULTS PERTAIN ONLY TO THE SAMPLE(S) SUBMITTED AND TESTED

**FIGURE 2. Water release characteristics of compacted rootzone materials – T5 Aquad4D Water Half Rate**



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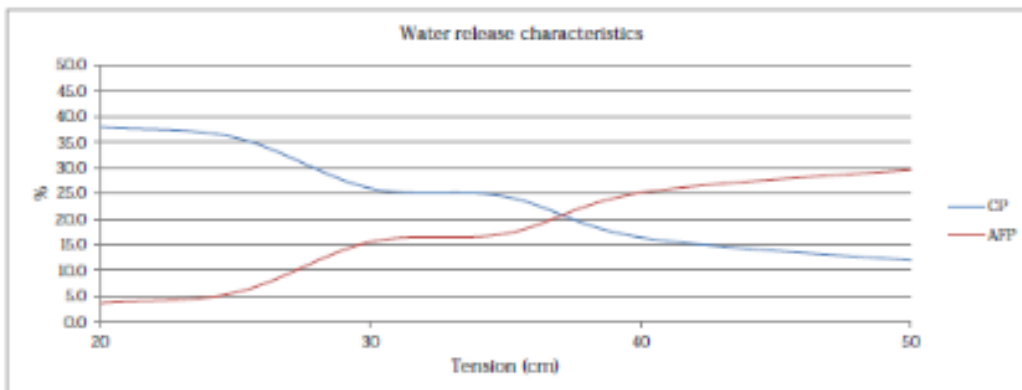
[enquiries@stidgroup.com](mailto:enquiries@stidgroup.com)

[www.strigroup.com](http://www.strigroup.com)

**WATER RELEASE CHARACTERISTICS OF COMPACTED ROOTZONE MATERIALS**

CLIENT:	AQUA 4D	RESULTS TO:	CT
		SAMPLE NO:	A20496/2
		DATE RECEIVED:	11/12/23
		DATE REPORTED:	21/12/23
DESCRIPTION:	T5	TEST RESULTS AUTHORIZED BY:	
CONDITION UPON ARRIVAL:	MOIST	Michael Baines, Laboratory Manager	

Particle density (g/cc)	2.636		
Bulk density (g/cc)	1.539		
TPS (%)	41.6		
Tension (cm)	CP (%)	AFP (%)	
20	38.0	3.7	
25	35.9	5.7	
30	26.0	15.6	
35	24.4	17.2	
40	16.5	25.2	
50	12.0	29.7	



THESE RESULTS PERTAIN ONLY TO THE SAMPLE(S) SUBMITTED AND TESTED



FIGURE 3. Turf quality

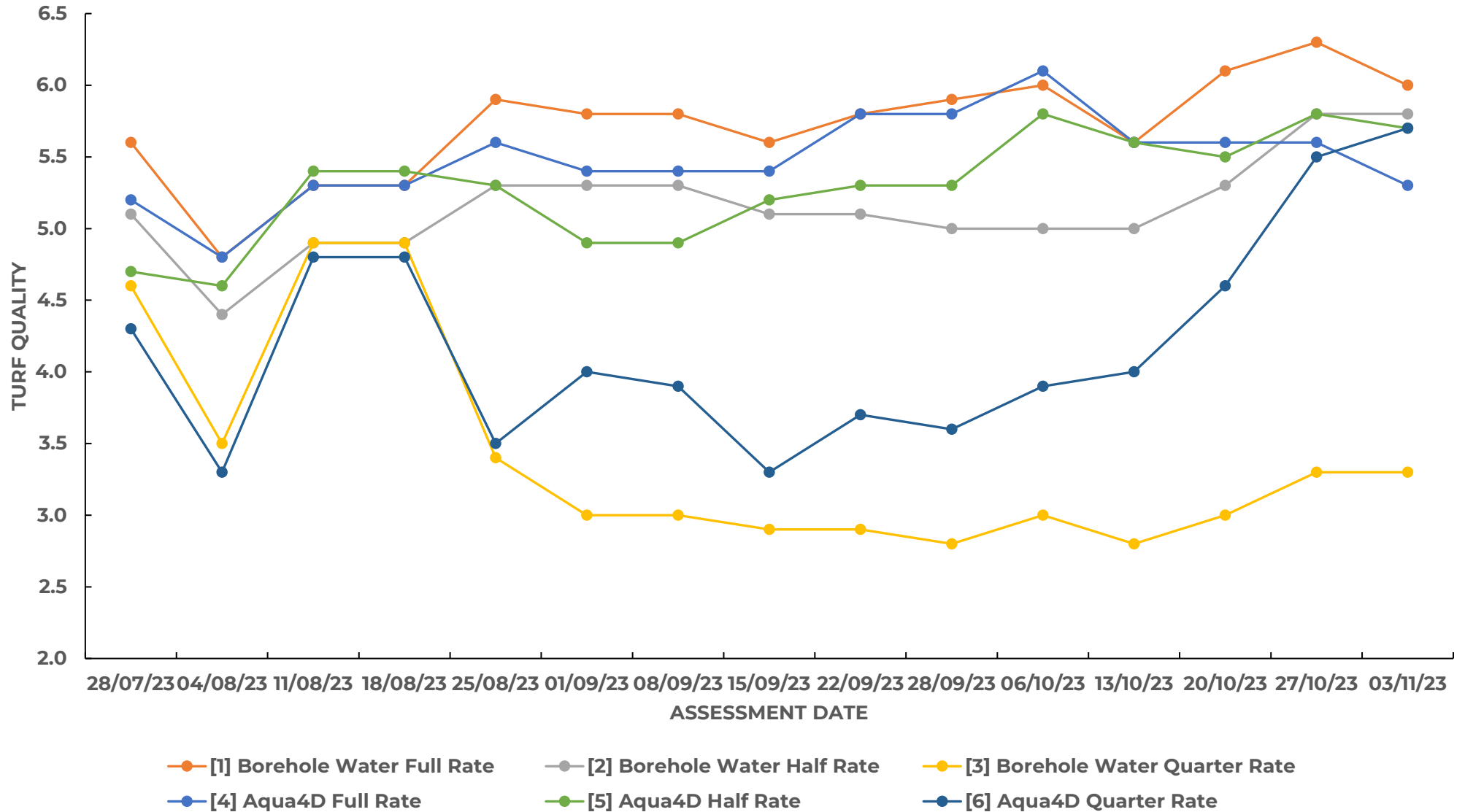
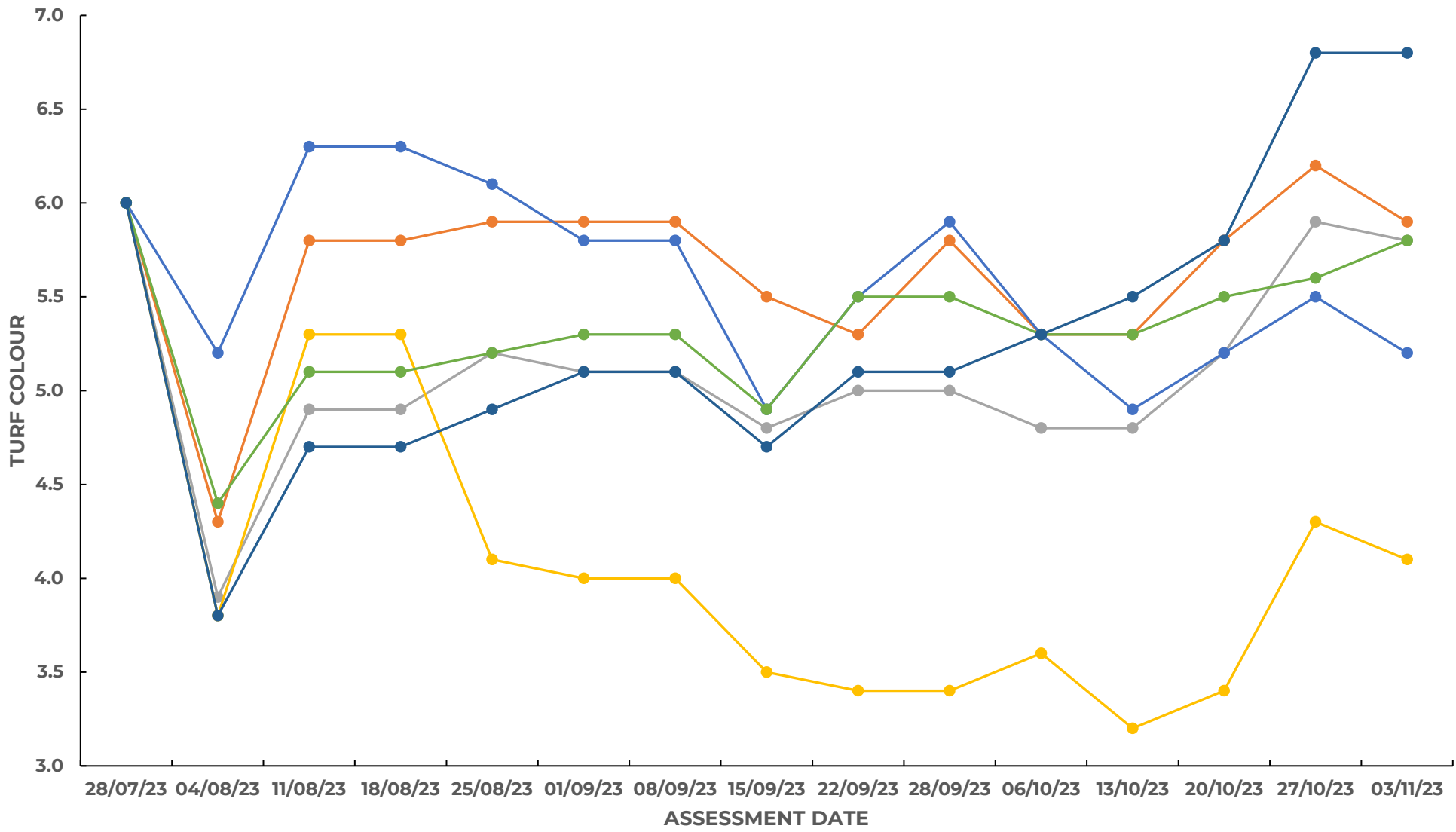


FIGURE 4. Turf colour



- [1] Borehole Water Full Rate
- [2] Borehole Water Half Rate
- [3] Borehole Water Quarter Rate
- [4] Aqua4D Full Rate
- [5] Aqua4D Half Rate
- [6] Aqua4D Quarter Rate

FIGURE 5. Turf density

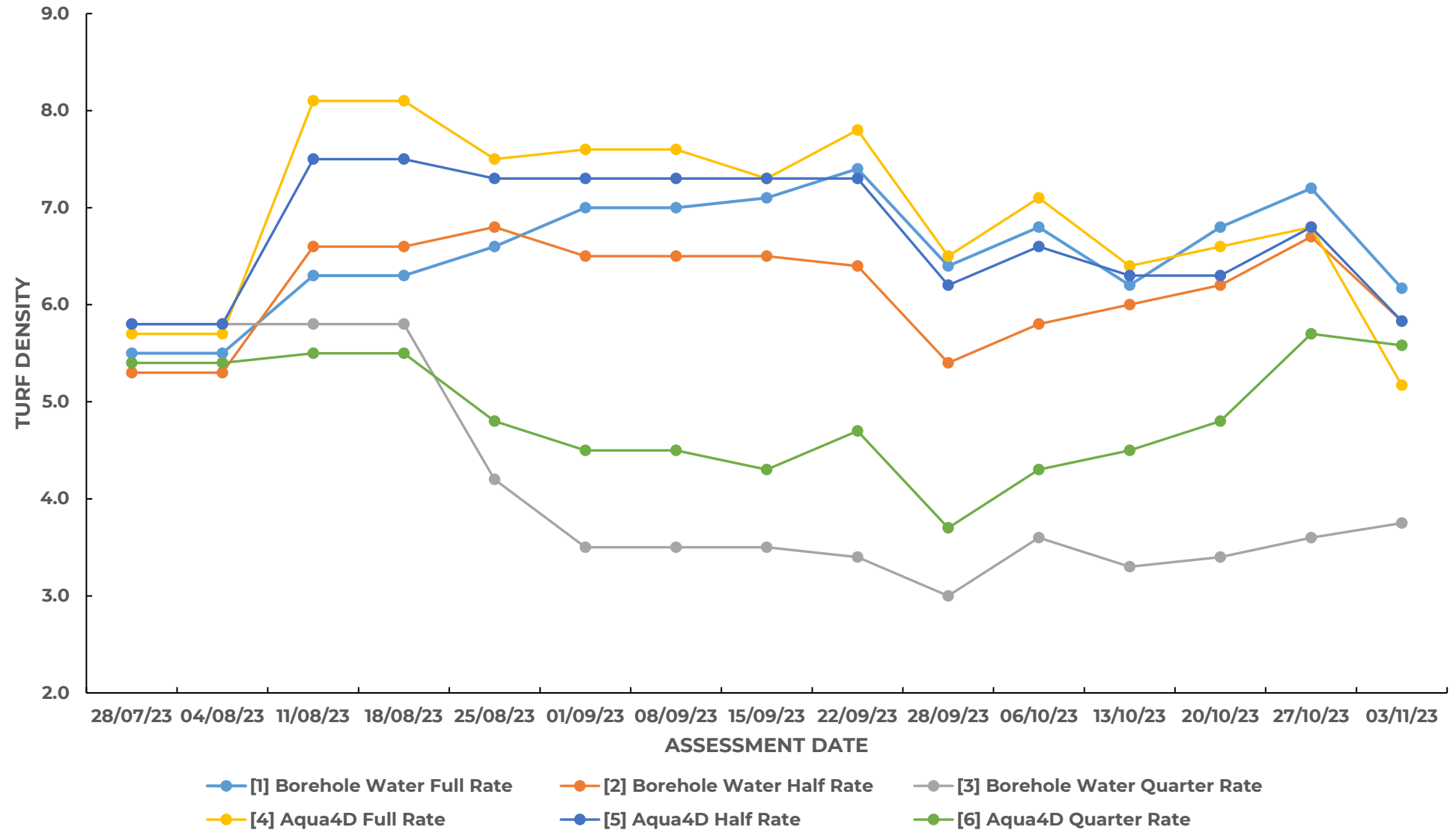


FIGURE 6. Turf uniformity

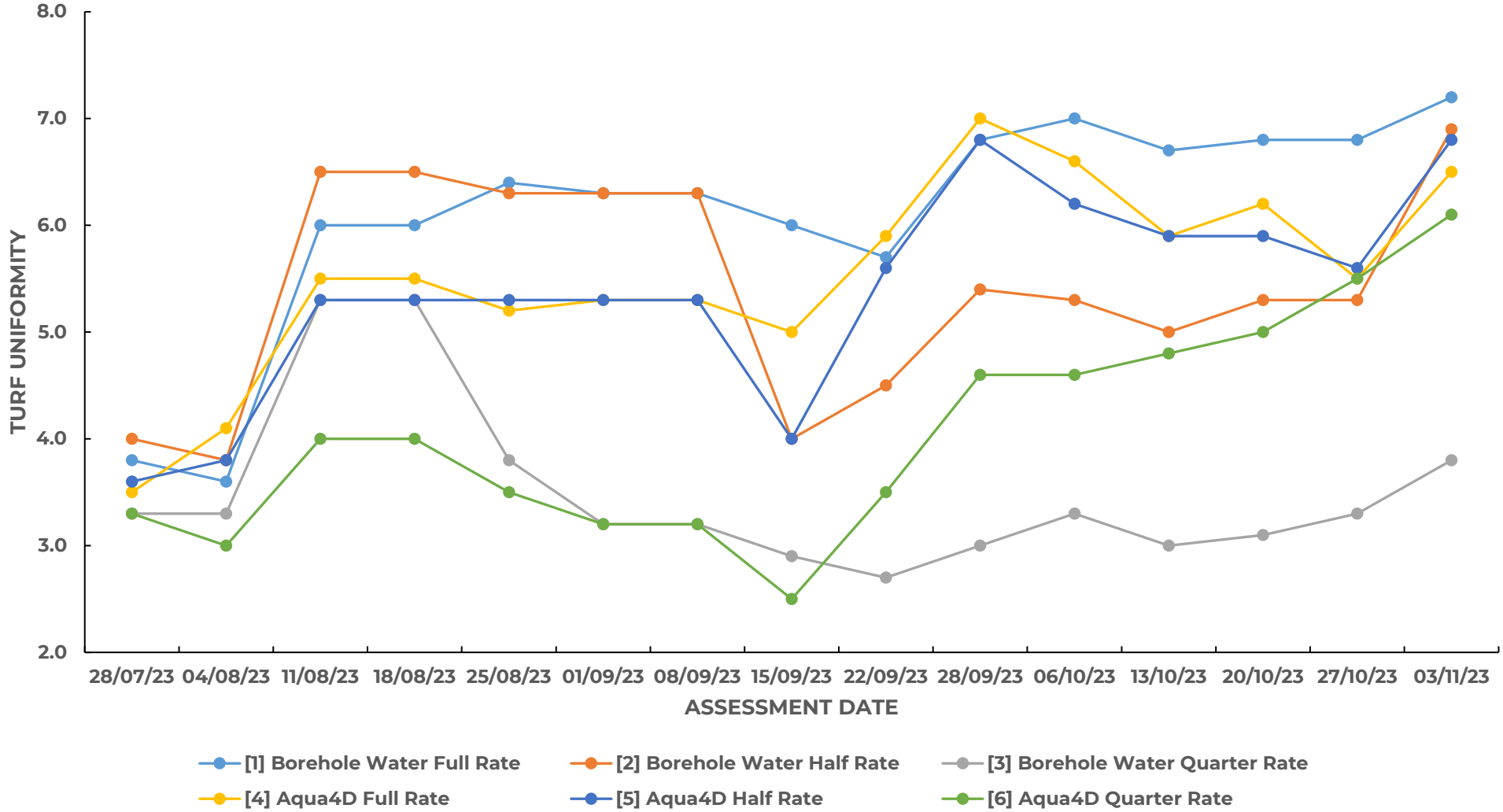
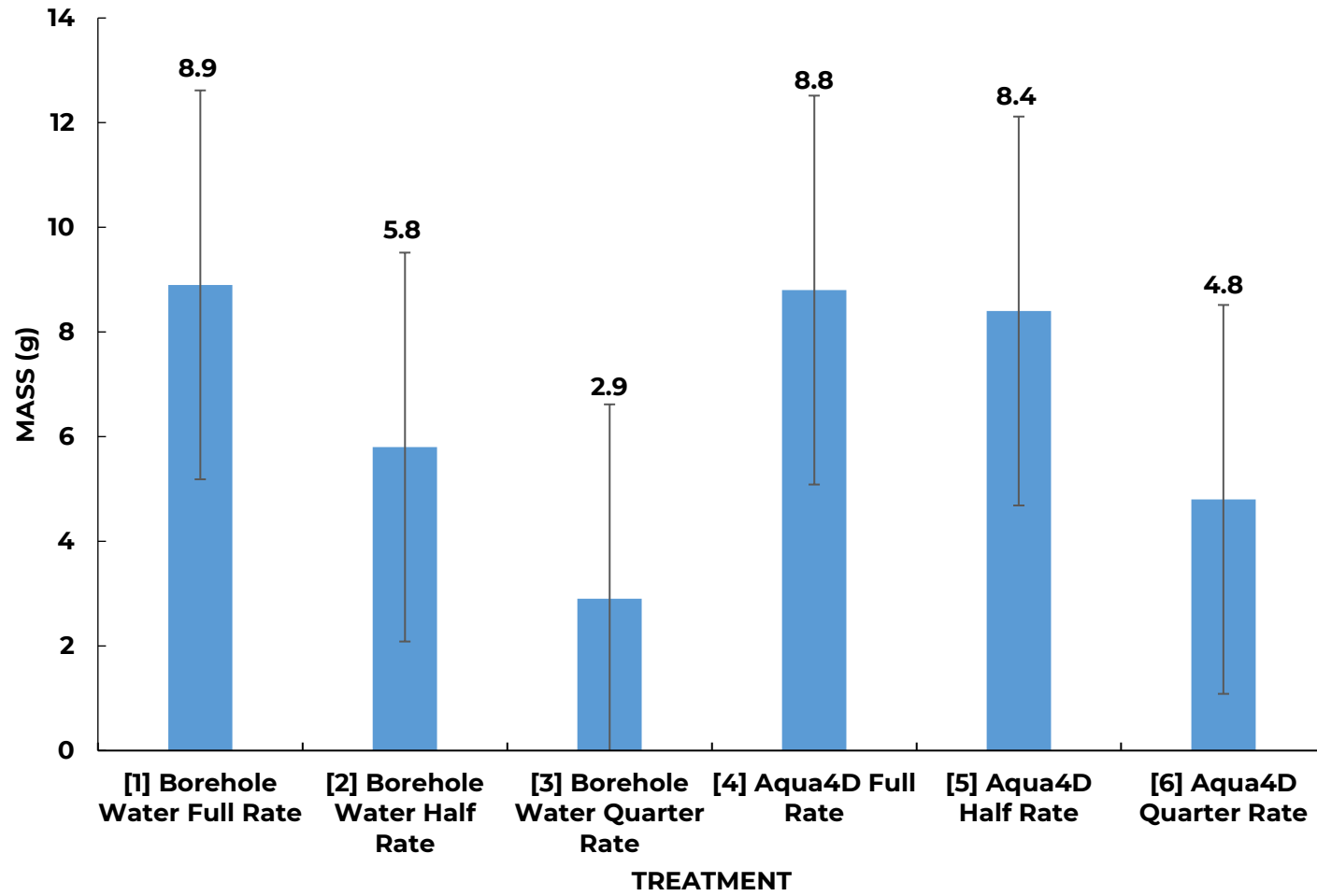


FIGURE 7. Root biomass



Appendix 3

**FIGURE 8. Trial plan**

<b>Block 1</b>	<b>Block 2</b>	<b>Block 3</b>	<b>Block 4</b>	<b>Block 5</b>	<b>Block 6</b>
T6	T1	T2	T5	T6	T6
T2	T6	T3	T2	T5	T3
T5	T4	T5	T3	T4	T2
T4	T5	T6	T6	T1	T4
T1	T3	T1	T1	T3	T1
T3	T2	T4	T4	T2	T5

## QUALITY STATEMENT

We confirm that this report is a true representation of the original data collected and that the Standard Operating Procedures referred to in the STRI Manual of Standard Operating Procedures, and those relevant to data collection, data preparation, archiving of data and preparation of reports have been implemented in full.

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(21/12/2023)

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(24/01/2024)

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(26/01/2024)

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