PRELIMINARY RESULTS

The Effect of Irrigation on Turf-grass Growth

AUGUST 22, 2024

Jacques Fouché: jacques.fch@gmail.com

Contents

Preliminary Statistical Report on the Effect of Irrigation on Turf-grass Growth

Introduction:

This preliminary report presents the initial findings of an exploratory study investigating the effects of various amounts of irrigation on turf-grass (*Kikuyu* and *Cynodon*) growth.

Methods:

Study Design: Randomised controlled trial.

Irrigation Method: Sprinkler irrigation at 5, 15, 20 and 25 mm without a control group (no irrigation).

Data Collection: Measurements of turf-grass dry weight, wet weight and height over four months.

Results:

Descriptive statistics

Table 1 Descriptive statistics: Kikuyu

Summary by Irrigation - Wet Weight

Irrigation	mean_value	median_value	sd_value	min_value	max_value	count
5	5.861458	4.4700	4.856748	1.370	26.640	48
15	8.888277	7.7910	5.016471	2.027	28.596	47
20	7.326667	6.4035	4.586340	1.218	21.172	48
25	12.557085	11.7700	6.506211	1.831	37.819	47

Summary by Irrigation - Dry Weight

Irrigation	mean_value	median_value	sd_value	min_value	max_value	count
5	1.957500	1.6250	1.451113	0.120	7.530	48
15	2.947106	2.7370	1.698217	0.691	9.536	47
20	2.692350	2.1555	1.884866	0.095	9.844	48
25	3.727098	3.5640	1.718580	0.272	8.823	47

Summary by Irrigation - Height

Irrigation	mean_value	median_value	sd_value	min_value	max_value	count
5	2.583333	2.5	0.7039655	1.5	4.5	48
15	3.148936	3.0	0.8335029	1.5	5.0	47
20	2.875000	2.5	1.1322168	1.5	6.0	48
25	3.148936	3.0	1.0576579	1.5	7.0	47

Table 2 Descriptive statistics: Cynodon

Summary by Irrigation - Wet Weight

Irrigation	mean_value	median_value	sd_value	min_value	max_value	count
5	5.978043	4.2750	5.865800	1.203	32.041	47
15	6.440391	4.9795	4.730677	0.132	19.276	46
20	6.747702	5.1440	5.353932	1.055	25.233	47
25	5.336217	4.6080	3.842482	0.846	18.925	46

Summary by Irrigation - Dry Weight

Irrigation	mean_value	median_value	sd_value	min_value	max_value	count
5	2.489660	1.912	2.055634	0.224	11.492	47
15	2.875565	2.382	2.021583	0.066	10.767	46
20	2.974681	2.625	2.197628	0.246	11.922	47
25	2.456311	1.872	1.681147	0.619	9.136	46

Summary by Irrigation - Height

Irrigation	mean_value	median_value	sd_value	min_value	max_value	count
5	1.672340	1.5	0.6917848	0.5	3.5	47
15	2.047826	2.0	0.6351690	1.0	3.0	46
20	1.865957	2.0	0.5779561	1.0	3.0	47
25	1.511957	1.5	0.5701057	0.5	3.0	46

Analysis of variances

Due to the non-normal distribution of the data, non-parametric analysis of variance was conducted using Kruskal-Wallis tests. These tests were used to evaluate the null hypothesis that there are no significant differences ($p < 0.05$) in the medians of growth parameters ('Wet Weight', 'Dry Weight', and 'Height') across different irrigation levels (5, 15, 20, and 25 mm)

Table 3 Analysis of variance results: Kikuyu

Kruskal-Wallis Test Results - Dry Weight

n	Statistic	df	p_value
190	32.19226	3	4.77e-07

Dunn Test Results - Dry Weight

comparisons	Z	P	P.adjust
15 - 20	1.072608	1.417235e-01	8.503408e-01
15 - 25	-2.281638	1.125537e-02	6.753224e-02
20 - 25	-3.366223	3.810255e-04	2.286153e-03
15 - 5	3.277824	5.230527e-04	3.138316e-03
20 - 5	2.216915	1.331446e-02	7.988674e-02
25 - 5	5.571439	1.263220e-08	7.579319e-08

Kruskal-Wallis Test Results - Wet Weight

n	Statistic	df	p_value
190	43.07136	3	2.38e-09

Dunn Test Results - Wet Weight

comparisons	Z	P	P.adjust
15 - 20	1.671755	4.728630e-02	2.837178e-01
15 - 25	-2.773031	2.776841e-03	1.666105e-02
20 - 25	-4.459343	4.110563e-06	2.466338e-05
15 - 5	3.528046	2.093200e-04	1.255920e-03
20 - 5	1.866138	3.101102e-02	1.860661e-01
25 - 5	6.315633	1.345286e-10	8.071717e-10

Kruskal-Wallis Test Results - Height

n	Statistic	df	p_value
190	13.4755	3	0.00371

Dunn Test Results – Height

comparisons	Z	P	P.adjust
15 - 20	2.1439444	0.0160186716	0.096112030
15 - 25	0.5484619	0.2916873841	1.000000000
20 - 25	-1.5926034	0.0556245976	0.333747586
15 - 5	3.2798887	0.0005192402	0.003115441
20 - 5	1.1419706	0.1267331176	0.760398705
25 - 5	2.7285477	0.0031806943	0.019084166

Table 4 Analysis of variance results: Cynodon

Kruskal-Wallis Test Results - Dry Weight

n	Statistic	df	p_value
186	4.023453	3	0.259

Dunn Test Results - Dry Weight

comparisons	Z	P	P.adjust
15 - 20	-0.2055841	0.41855790	1.0000000
15 - 25	1.1154321	0.13233265	0.7939959
20 - 25	1.3269971	0.09225482	0.5535289
15 - 5	1.4502730	0.07349120	0.4409472
20 - 5	1.6648320	0.04797314	0.2878388
25 - 5	0.3288600	0.37113076	1.0000000

Kruskal-Wallis Test Results - Wet Weight

n	Statistic	df	p_value
186	3.093318	3	0.377

Dunn Test Results - Wet Weight

comparisons	Z	P	P.adjust
15 - 20	-0.15233417	0.43946169	1.0000000
15 - 25	1.12995436	0.12924773	0.7754864
20 - 25	1.28834730	0.09881255	0.5928753
15 - 5	1.18625959	0.11775990	0.7065594
20 - 5	1.34584906	0.08917560	0.5350536
25 - 5	0.05024646	0.47996300	1.0000000

Kruskal-Wallis Test Results - Height

n	Statistic	df	p_value
186	17.15278	3	0.000657

Dunn Test Results - Height

comparisons	Z	P	P.adjust
15 - 20	1.123858	1.305367e-01	0.7832203229
15 - 25	3.845591	6.013119e-05	0.0003607871
20 - 25	2.742353	3.050037e-03	0.0183002224
15 - 5	2.651842	4.002701e-03	0.0240162079
20 - 5	1.536266	6.223657e-02	0.3734194067
25 - 5	-1.214369	1.123035e-01	0.6738208065

For all growth parameters of Kikuyu, the null hypothesis was rejected, indicating that at least one group's distribution differs from the others. The Dunn test was then used as a post-hoc analysis following the Kruskal-Wallis tests to identify significant differences among groups. This test provided the adjusted p-values ('P.adjust') for pairwise comparisons, pinpointing which specific groups differed from each other. For Cynodon, the null hypothesis could only be rejected for the Height parameter.

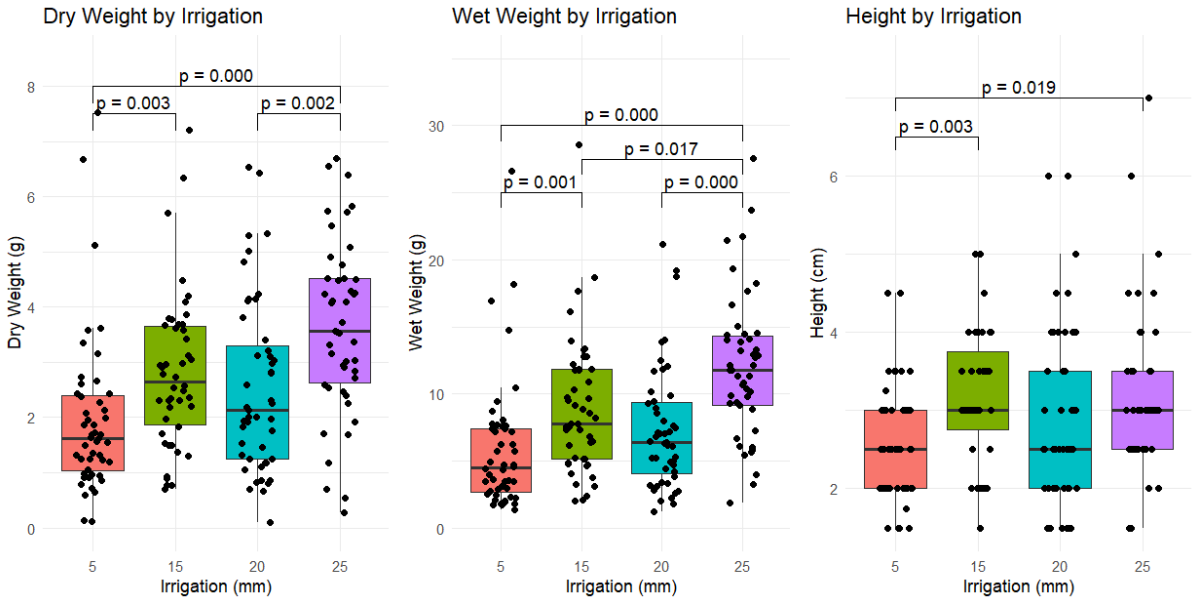

Figure 1 Analysis of variance boxplots for Kikuyu indicating the Dunn test p-values of significant differences between groups.

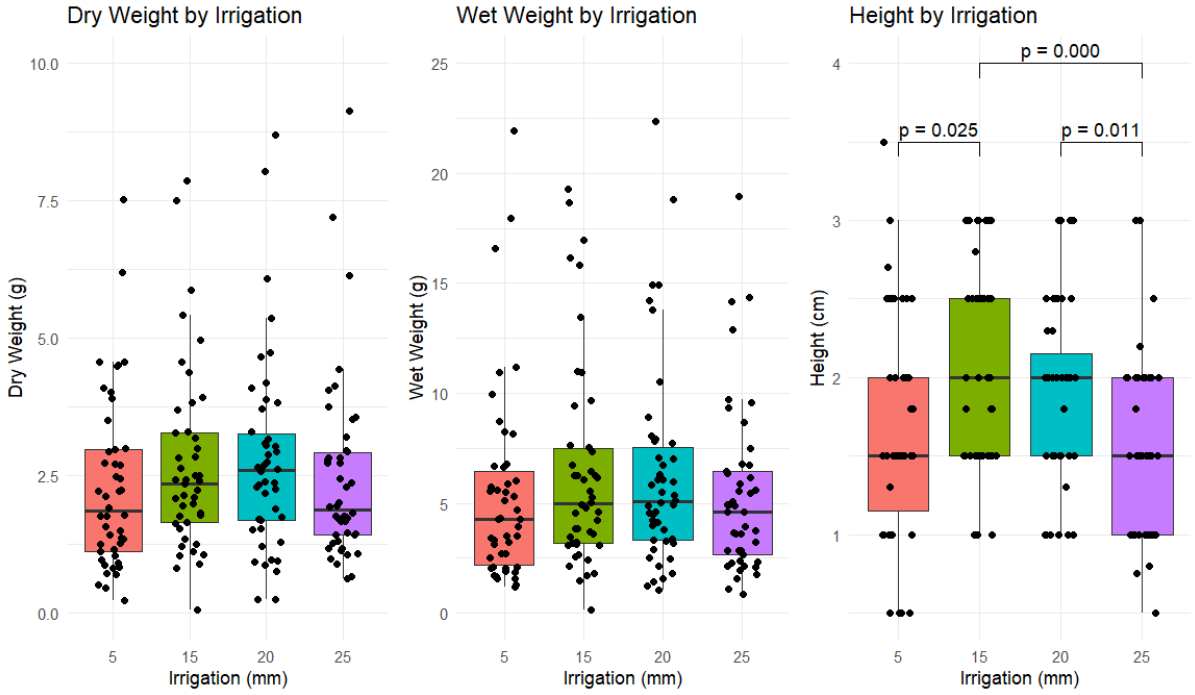

Figure 2 Analysis of variance boxplots for Cynodon indicating the Dunn test p-values of significant differences between groups.

Analysis of variance results by rainfall quantile

A linear regression analysis was conducted to examine the relationship between irrigation levels and rainfall and was found to be statistically significant ($R^2 = 0.1723$: $F_{2, 187} = 19.46$: $p < 0.001$) with rainfall coefficient values of \beta = -0.021, SE = 0.005, t = -3.964 and $p < 0.001$. Therefore, rainfall was categorised in quantiles (Low: 0% < 1.575mm, Moderate: 25% < 3.700mm, High: 50% < 32.575mm, Very High: 75% < 72.800mm) and analyses of variance performed for each quantile.

Table 5 Analysis of variance results by rainfall quantile: Kikuyu

Kruskal-Wallis Test Results - Low Rainfall

Statistic	df	p_value
6.435646	3	0.0922353

Dunn Test Results - Low Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	0.8921340	0.37232112	1.0000000
15 - 25	-0.8259519	0.40883135	1.0000000
20 - 25	-1.7566994	0.07896905	0.4738143
15 - 5	1.4890961	0.13646208	0.8187725
20 - 5	0.6103786	0.54161103	1.0000000
25 - 5	2.3670781	0.01792915	0.1075749

Kruskal-Wallis Test Results - Moderate Rainfall

Statistic	df	p_value
15.62403	3	0.001354061

Dunn Test Results - Moderate Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	-1.116546	0.2641883838	1.0000000000
15 - 25	-2.325637	0.0200379168	0.1202275010
20 - 25	-1.233633	0.2173395572	1.0000000000
15 - 5	1.488728	0.1365589203	0.8193535218
20 - 5	2.605275	0.0091800657	0.0550803939
25 - 5	3.781642	0.0001557972	0.0009347832

Kruskal-Wallis Test Results - High Rainfall

Statistic	df	p_value
1.97449	3	0.5777183

Dunn Test Results - High Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	0.3790877	0.7046227	1
15 - 25	-0.2332847	0.8155403	1
20 - 25	-0.6123724	0.5402914	1
15 - 5	1.0789419	0.2806136	1
20 - 5	0.6998542	0.4840184	1
25 - 5	1.3122266	0.1894437	1

Kruskal-Wallis Test Results - Very High Rainfall

Statistic	df	p_value
22.29288	3	5.668909e-05

Dunn Test Results - Very High Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	2.1725231	2.981623e-02	0.1788973856
15 - 25	-1.5892954	1.119937e-01	0.6719622936
20 - 25	-3.7618185	1.686825e-04	0.0010120947
15 - 5	2.5078790	1.214583e-02	0.0728749528
20 - 5	0.3353559	7.373566e-01	1.0000000000
25 - 5	4.0971744	4.182238e-05	0.0002509343

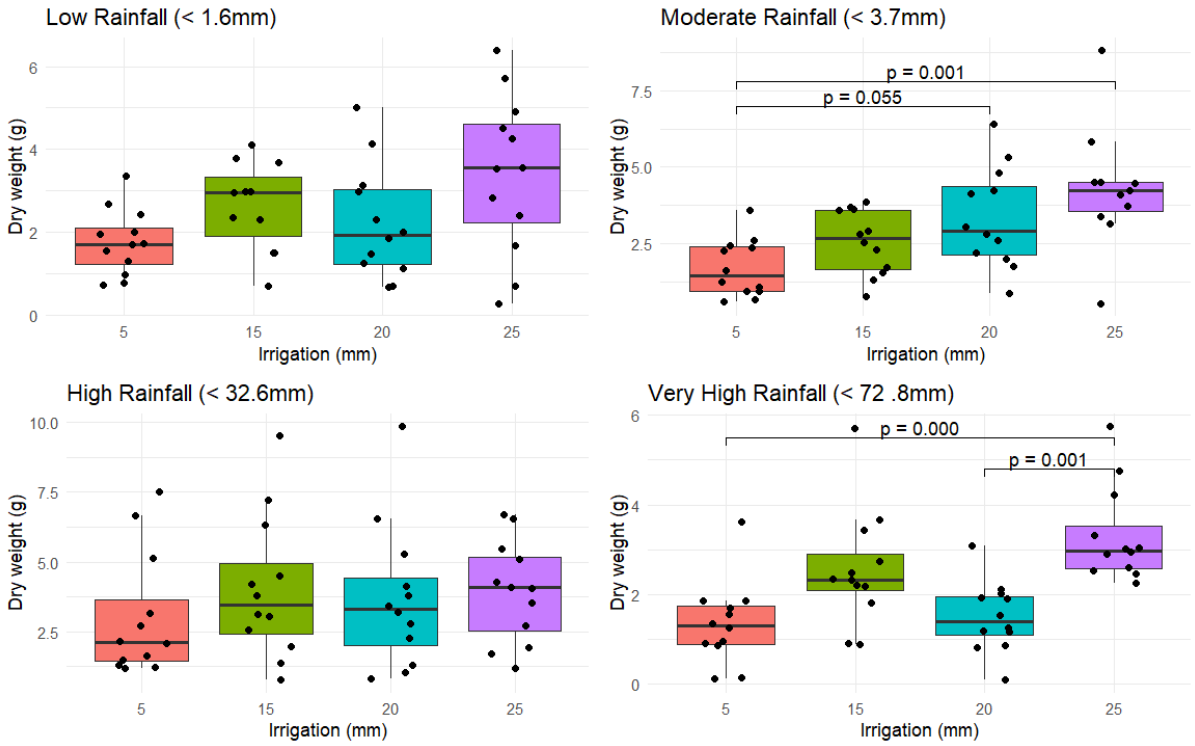

Figure 3 Dry Weight analysis of variance results by rainfall quantile for Kikuyu indicating the Dunn test p-values of significant differences between groups.

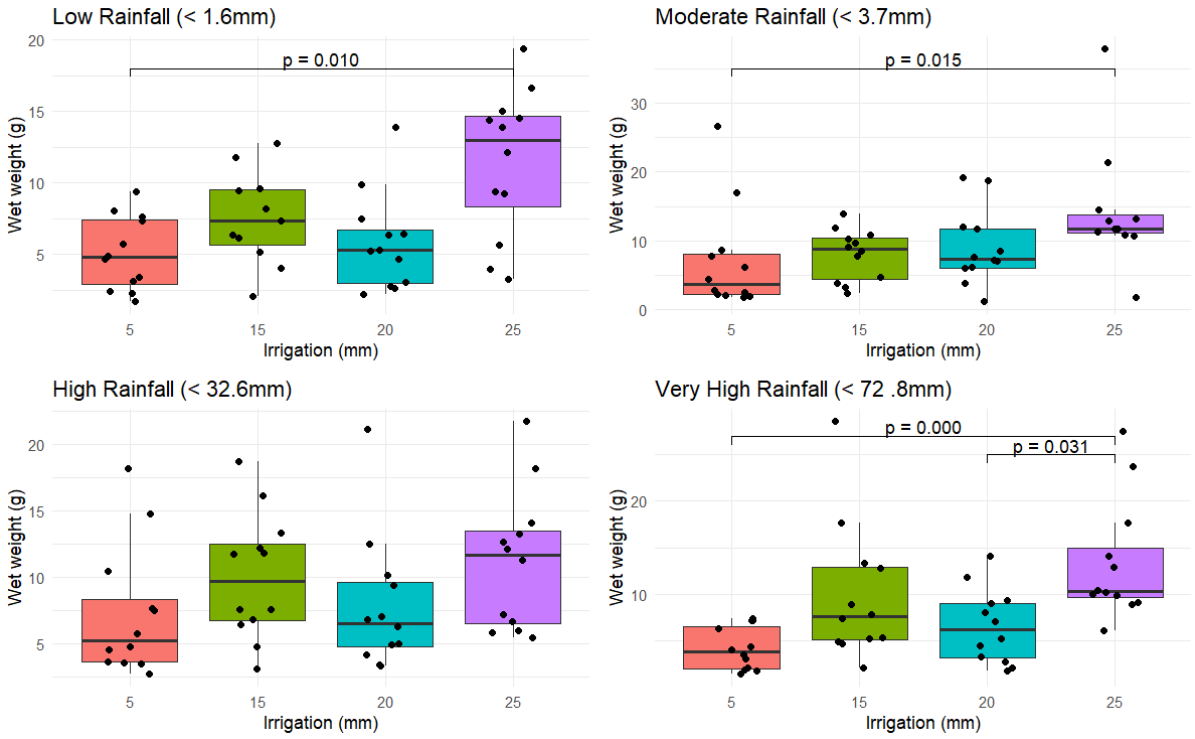

Figure 4 Wet Weight analysis of variance results by rainfall quantile for Kikuyu indicating the Dunn test p-values of significant differences between groups.

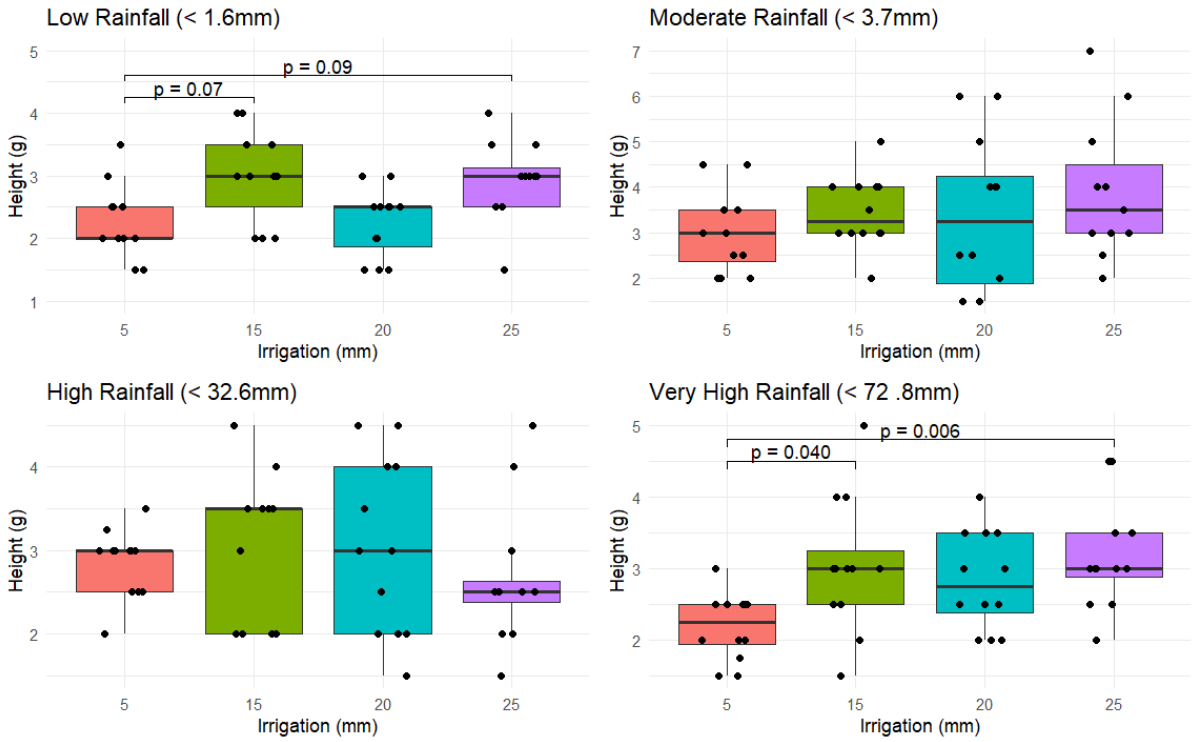

Figure 5 Height analysis of variance results by rainfall quantile for Kikuyu indicating the Dunn test p-values of significant differences between groups.

Table 6 Analysis of variance results by rainfall quantile: Cynodon

Kruskal-Wallis Test Results - Low Rainfall

Statistic	df	p_value
5.760365	3	0.1238692

Dunn Test Results - Low Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	0.8572375	0.39131365	1.0000000
15 - 25	1.0483236	0.29448953	1.0000000
20 - 25	0.2136333	0.83083302	1.0000000
15 - 5	2.3594312	0.01830297	0.1098178
20 - 5	1.5359551	0.12454938	0.7472963
25 - 5	1.2885604	0.19755094	1.0000000

Kruskal-Wallis Test Results - Moderate Rainfall

Statistic	df	p_value
0.9407535	3	0.8155836

Dunn Test Results - Moderate Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	-0.34944121	0.7267581	1
15 - 25	0.49622422	0.6197362	1
20 - 25	0.85318115	0.3935589	1
15 - 5	0.42185819	0.6731285	1
20 - 5	0.77881513	0.4360886	1
25 - 5	-0.07603738	0.9393894	1

Kruskal-Wallis Test Results - High Rainfall

Statistic	df	p_value
1.39406	3	0.7069276

Dunn Test Results - High Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	-0.6252659	0.5317966	1
15 - 25	0.5210549	0.6023285	1
20 - 25	1.1463208	0.2516624	1
15 - 5	-0.2620809	0.7932591	1
20 - 5	0.3494412	0.7267581	1
25 - 5	-0.7716827	0.4403024	1

Kruskal-Wallis Test Results - Very High Rainfall

Statistic	df	p_value
0.9577742	3	0.8114678

Dunn Test Results - Very High Rainfall

Comparison	Z	P.unadj	P.adj
15 - 20	-0.4689630	0.6390961	1
15 - 25	0.5049836	0.6135703	1
20 - 25	0.9636385	0.3352272	1
15 - 5	0.1414333	0.8875277	1
20 - 5	0.6103963	0.5415993	1
25 - 5	-0.3666591	0.7138733	1

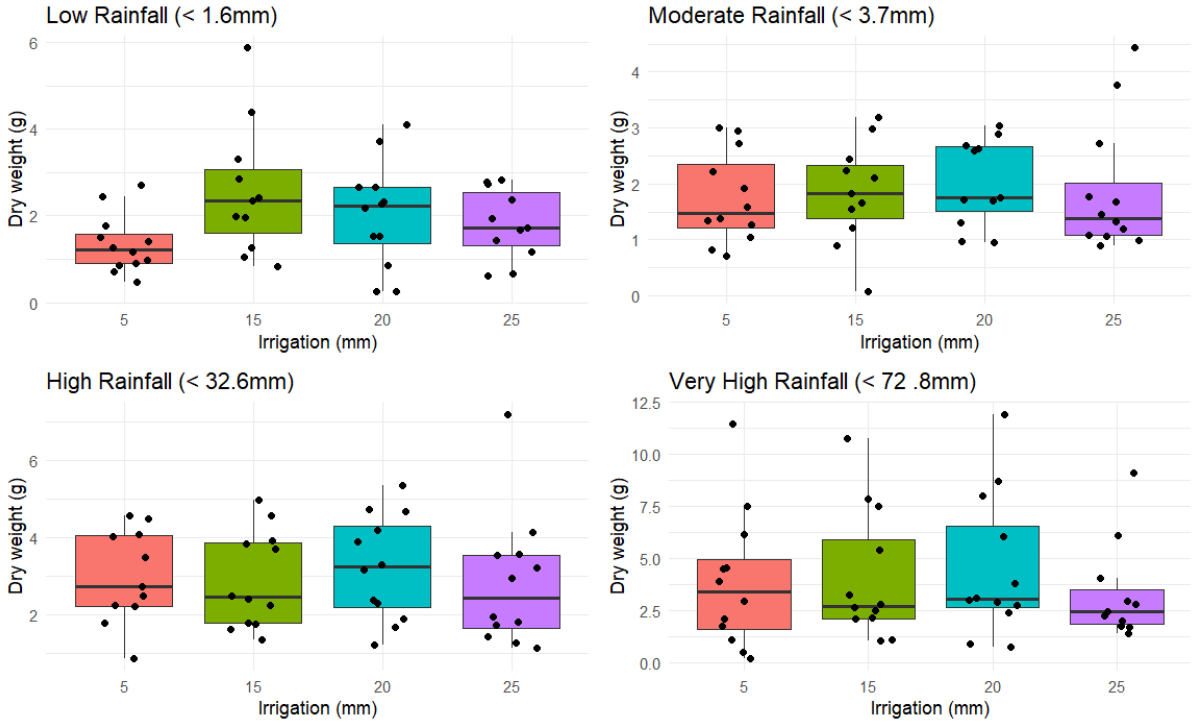

Figure 6 Wet Weight analysis of variance results by rainfall quantile for Cynodon indicating the Dunn test p-values of significant differences between groups.

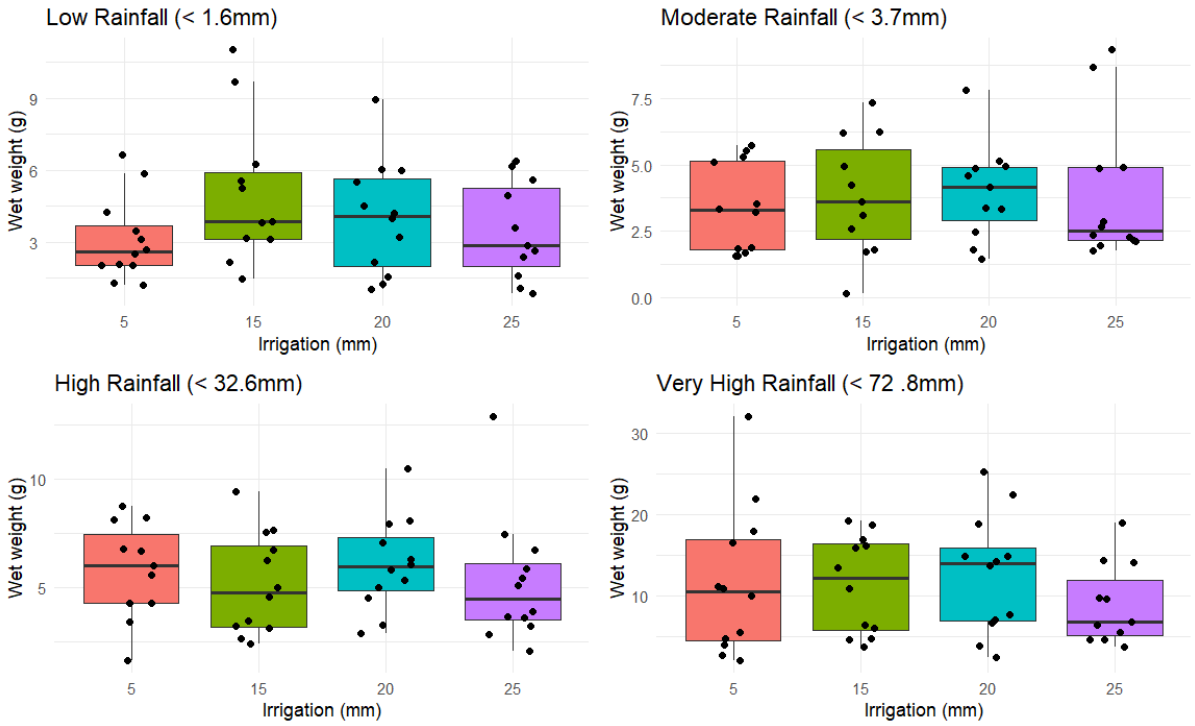

Figure 7 Wet Weight analysis of variance results by rainfall quantile for Cynodon indicating the Dunn test p-values of significant differences between groups.

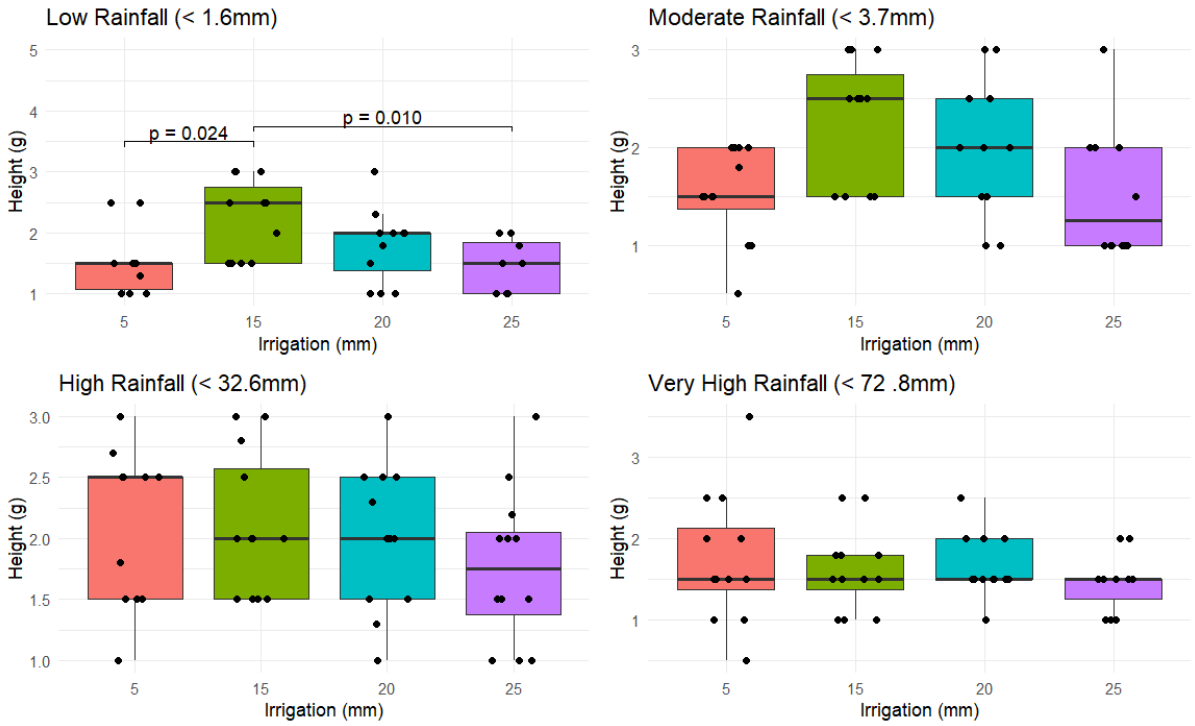

Figure 8 Height analysis of variance results by rainfall quantile for Cynodon indicating the Dunn test p-values of significant differences between groups.

Tables 5 and 6 and the accompanying box plots (Figures 3 to 8) indicate significant differences ($p < 0.05$) between the irrigation treatment groups by rainfall quantile.

Discussion:

Some statistical outliers were identified and removed before the analysis. The preliminary results indicate that *Kikuyu*, and to a lesser extent *Cynodon*, had significant differences in the measured growth parameters (‘Dry Weight, Wet Weight and Height) when comparing the different irrigation treatments (5, 15, 20 and 25 mm). It is recommended that a control group that receives 0 mm irrigation is introduced so that the treatment groups can be compared to the control group using Dunnet’s test, which is less strict and more appropriate. Further clarity regarding when irrigation did not occur due to rainfall may provide a better understanding of the impact of irrigation on growth.

Data Availability

The data sets and analysis scripts used in this study can be made available on the GitHub repository upon request [GitHub Repository https://github.com/JacquesFch]. The repository can also be made public at your request. Making a repository public on GitHub has several benefits. It allows others to verify the results, enhancing the credibility and reproducibility of the research. It makes collaboration easy and can build upon the work. It can lead to more citations and recognition and contribute to the open science movement, making research accessible to everyone and aligning with the principles of transparency, accessibility, and shared knowledge.