Assessment of Growth, Photosynthetic and Biomass Characteristics of Selected Fodder Grass Varieties Under Standardized Water Regimes

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Abstract

Fodder grasses are vital for global livestock and sustainable agriculture, but lack of understanding of their specific water needs to optimize photosynthesis, biomass, and overall growth. This gap was investigated by comparing three fodder grass species CO3, CO4 and Super Napier (SN) under controlled, standardized water conditions (10 liters/day) within protected environments. Data was gathered at 3 – 6 weeks after planting (WAP). Fodder varieties were insignificant in plant height, leaf production rate (LPR) and leaf width. But all the varieties experienced a sharp decline in LPR at 4WAP before rebounding in subsequent weeks. Leaf length and tillers/plant were significant where CO3 exhibited highest leaf length (120cm). SN displayed significantly fewer tillers (9 at 6WAP). Photosynthetic efficiency, as measured by quantum yield and chlorophyll content, remained high and insignificant across varieties at 6WAP, suggesting similar light-harvesting capacities. Stomatal conductance was insignificant across varieties but lower values observed at 4WAP. Biomass performances at 3WAP, CO3 had the highest fresh weight (189.6g), significantly more than CO4 (146.7 g) and SN (84.7 g) while CO3 and CO4 were insignificant in dry weight, but SN's dry weight (36.4 g) was significantly lower. At 6 WAP, the fresh weights of CO3 and CO4 were insignificant. However, SN's fresh weight (1198 g) was significantly lower than CO3 and CO4. At 6 WAP, dry weight differed significantly (p = 0.043), with CO3 having the highest (613.7g). Overall, CO3 and CO4 generally out-yielded Super Napier in both fresh and dry biomass at 6 WAP. The results can inform the development of more efficient cultivation practices and enhance the resilience and productivity of fodder systems, particularly for high-yielding varieties like CO3 and CO4, in water-limited regions

Keywords: Biomass, Fodder grasses, Growth, Photosynthesis, Water requirements

I. INTRODUCTION

Fodder grasses encompass various species with slender leaves, cultivated across diverse climates and soils, and are categorized into five primary types for dairy cattle: legume, cereal, grass, tree, and Azolla (Kumara et al., 2022). Their classification is based on botanical characteristics, photosynthetic pathways (C3 and C4), growth habits, and climatic conditions, aiding in selecting optimal species for specific environments to maximize productivity and sustainability (Rathod and Dixit, 2019; Thomas and Thomas, 2019). These grasses exhibit valuable growth traits, including vigorous root systems, rapid vegetative growth, dense clump formation, and tolerance to grazing, all contributing to their importance in sustainable livestock farming (Saini et al., 2007). Many primarily utilize the C4 photosynthetic pathway, which enhances their efficiency in carbon dioxide capture, especially in high-light, high-temperature, and drought conditions, optimizing water-use efficiency and ensuring a continuous supply of nutritious forage (Gómez, et al., 2013).

Fodder grasses are renowned for their impressive biomass characteristics. These include high biomass yield due to rapid growth and efficient photosynthesis, a balanced biomass composition comprising leaves, stems, and sometimes inflorescences, a favourable leaf-to-stem ratio for improved palatability and digestibility, rapid regeneration for a consistent forage supply, and their contribution to soil health by adding organic matter and preventing erosion, making them

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crucial components of sustainable farming practices (Glamoclija et al., 2011).

Water is a critical factor influencing the growth and biomass production of fodder grasses. Water requirements vary significantly depending on the specific grass species, climate, soil type, and irrigation methods. Multiple studies (Nawaz et al., 2016) indicate that water stress in plants has a significant impact on various growth aspects. This includes changes to the plant's anatomy, morphology, physiology, and (Anjum et al., 2011). These changes can affect leaves' water potential, stomata resistance and conductance, transpiration, photosynthesis, leaf temperature, and leaf withering. Lee (2018) found that environmental stresses, such as higher light intensity and lower soil moisture, can cause changes in the composition and structure of leaves. These changes can affect how leaves take in and store food because they tend to make more hairs, stomata sink deeper into the epidermis, more bulliform cells get involved in rolling and unrolling leaves, and cuticle synthesis gets better (Garrido *et al*., 2014).

Hence, C4 grasses generally exhibit higher water-use efficiency compared to C3 grasses, enabling them to thrive in arid and semi-arid regions with limited water availability (Israel et al., 2022). Adequate and timely irrigation is crucial for optimal growth, especially during periods of drought. However, excessive water can lead to waterlogging, which can hinder root development and reduce biomass yield. Efficient irrigation practices, such as drip irrigation, can help minimize water loss and optimize water use for fodder production.

Despite the established significance of fodder grasses in livestock production and their efficient C4 photosynthetic pathway, there remains a notable research gap concerning their precise water requirements for optimizing photosynthetic rates, biomass production, and overall growth. This lack of specific data hinders the development of efficient irrigation strategies crucial for sustainable fodder cultivation, particularly in regions facing water scarcity. Therefore, this study aims to evaluate the photosynthetic, growth, and biomass performance of three selected grass species, CO3, CO4, and Super Napier (SN) under controlled protected house experiments with standardized water conditions. This research will provide critical insights into their physiological responses to water availability, informing improved cultivation practices and enhancing the resilience and productivity of fodder systems.

II. MATERIAL AND METHODS

A. Location of the study

Present experiment was carried out at Malwatta (7°20'N and 81°44'E; elevation 16.0 m above sea level), Ampara district (DL2b) from August to December 2023. This research station experiences a mean annual temperature of 30°C and annual precipitation ranging from 1400 mm. The soil type is non-calcic brown soil with a sandy texture and slightly acidic pH (Begum et al., 2018).

B. Preparation of polytunnels

A total of 3 high yielding improved cultivars (CO3, CO4, and SN) were cultivated. Total of nine polytunnels were selected, each sized by 11.5*7.5 feet^2, were divided into three sections. Each polytunnel had the same climate conditions. The growing media consisted soil: silt: compost mixed in a ratio of 1:1:1 for the soil base material. Super Napier, CO3, and CO4 grass plant stem cuttings were planted in each polytunnel comprised with six pieces of grass were planted in each bed. Each fodder species was evenly spaced, with 50 x 50 cm.

C. Management of the fodders

All three fodder species was planted in each tunnel consisted and managed with similar environmental condition. Each tunnel was manually irrigated with 10 liters per day

D. Data Collection and analysis

After the grass established, at 3 to 6 weeks of intervals, growth morphological parameters such as plant height, leaf length, leaf width, number of leaves, and number of tillers were measured. Consequently, physiological parameters a such leaf stomatal conductivity, chlorophyll fluorescence (quantum yield efficiency), and chlorophyll content were measured. In addition. at harvesting stage (6WAP), fresh and dry weights were measured.

Plant leaf length was measured using a string and a piece of the tape. Newly fully expanded leaves were recorded. Two readings of leaf width were taken from one leaf. For a single plant leaf, at least two measurements were obtained from each plant. Plant height was measured from the soil base root system to the newly added leaf with a measuring tape.

Using a chlorophyll meter (SPAD 502, Konica Minolta, USA), the amount of chlorophyll was measured and recorded in Soil-Plant-Analysis-Development (SPAD) units. The superior fully expanded leaves were used to obtain three readings: one at the base of the leaf, one in the middle of the leaf, and one at the tip of the leaf (apart from the midrib). The data were taken from four randomly selected plants from each plot.

Stomatal conductance was measured using a porometer device (Porometer SC-1 Decagon Devices, USA). The measurements from the fully expanded leaf from each reading taken at their bases and tips. Four plants were chosen from a single bed in order to gather data. From a single plant leaf, at least two measurements were obtained. A measurement period between 9:00 a.m. and 11:00 a.m. was observed.

Using a fluor pen (FP 100, Photon Systems Instruments, Czech Republic), chlorophyll fluorescence characteristics, including quantum yield (Qy), were examined in leaves. Two readings were taken at the base and tip of the leaf.

Fodder grasses were harvested in the third week and the sixth week. In the third week, five centimeters above the root of the fodder were cut, and then the fresh weight was measured. The harvest was then placed in a dry oven at a temperature of 80°C for constant weight (at least 72 hours), and the dry weight was measured.

E. Data Analysis

The experimental design was a completely randomized design (CRD) with three treatments and nine replicates. assuming that all the environmental and climatic factors within the polytunnels were the same. SPSS software (Version 25) was used to statistically analyze the data. Descriptive statistics and one way ANOVA was performed.

III. RESULTS AND DISCUSSION

A. Growth parameters of fodder varieties

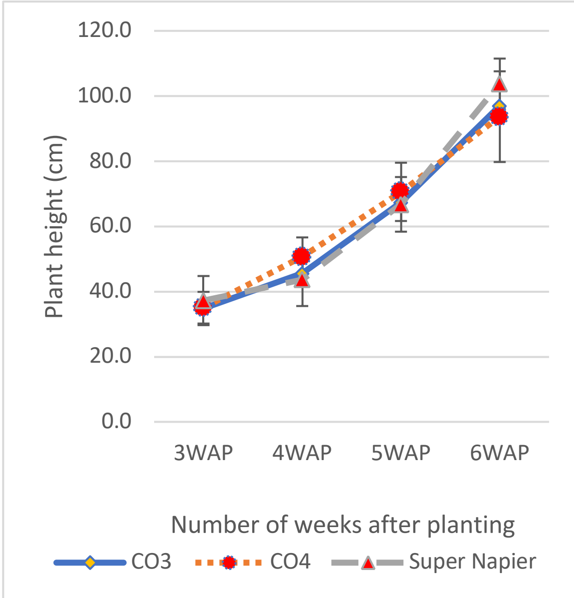

Figure 01: Variations in plant height of fodder varieties over the six-weeks of protected house experiment

Figure 01 depicts the plant height of tested fodder varieties at growth intervals. Plant height significantly increased at 5 and 6 weeks after planting across varieties. However, no significant differences were observed across the tested varieties. CO-3 grass grown in a northern part of Sri Lanka reach 145 cm of plant height at 8 WAP (Samini and Premaratne, 2017). Wangchuk *et al* (2015) reported similar findings under open field circumstances. Mounika et al., (2015) reported that in Bhutan, at one year of cultivation, CO3 can reach 175 cm height in open field conditions. According to Epasinghe *et al* (2012), CO-3 had a mean plant height of 172 cm during the ninth week of growth, which was greater compared to the CO3 growth in Sri Lanka's wet zone. In another report (Sathees and Sivaranjani, 2022) the Napier grass in open field conditions (30cm × 30cm), resulted in the highest plant height of 153 cm at 8 WAP.

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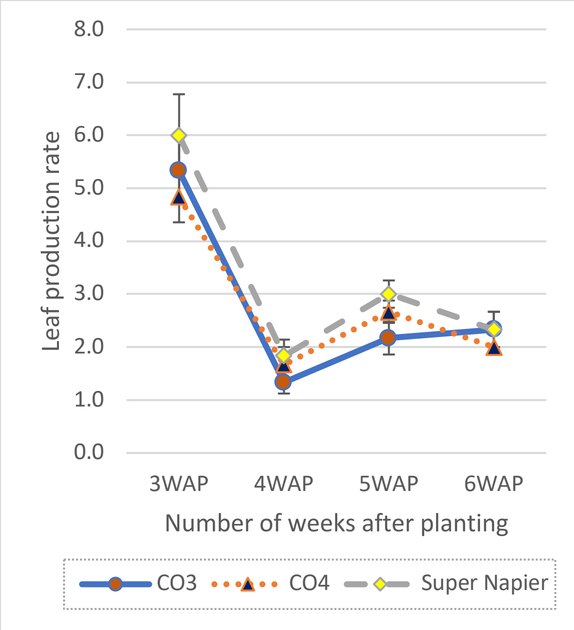

Figure 02: Leaf production rates of fodder varieties during six weeks of protected house experiments

In case of leaf production rates per week, as depicted in figure 02, there were no significant differences among the tested varieties. However, the data reveals a consistent trend of decreasing leaf production rates per week across all fodder varieties from 3 to 5 WAP. While all varieties showed a decline in leaf production rates from 5 to 6 WAP, this could indicate a shift in resource allocation towards other growth processes, such as stem elongation or reproductive development, as the plants mature. According to a field study conducted (45 x 45 cm) in India on CO3, plants exhibited a high number of leaves (156.15) in the 13th week (Mounika *et al.,* 2015).

Further, the hybrid Napier variety CO-3 produced the most leaves at the 4th, 6th, and 8th weeks of growth, with 24,73, 44.33, and 109.67 leaves, respectively (Premaratne and Premalal, 2006). According to Sarmini and Premaratne (2017), since leaves have more nutritional qualities than the plant's stem, the quantity of CO3 leaves on a plant plays a critical role in controlling the growth and forage yield of fodder species. Different outcomes could be caused by differences in maturity level, climate, and plant spacing (Ibrahim et al., 2014). In a prior investigation, 56 days after sowing, Napier grass produced more leaves (93.67). Based on a study done by Sathees and Sivaranjani (2022), Sri Lanka's dry zone (Kilinochchi area) produced the highest number of leaves per tiller (11.33 leaves) at 56 days after planting (Sathees and Sivaranjani, 2022) when it is planted in 30cm x 30cm spacing.

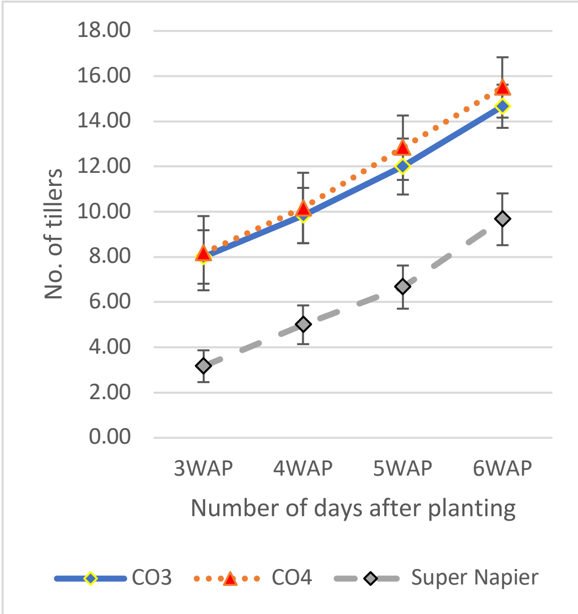

Figure 03: Number of tillers produced over the six-weeks of protected-house experiments

Tillers, or shoots that develop from the base of the plant, are the primary units of growth in many grasses, contributing significantly to overall biomass yield (Lakshan et al., 2024). A higher number of tillers generally translates to increased leaf and stem production, which directly impacts the fodder's potential for providing nutritious feed for livestock (Lakshan, 2018). Figure 03, illustrates the tiller production across varieties of fodders at WAP. Number of tillers were observed in an increasing pattern from 3 to 6WAP despite the varieties. However, tiller production was significant across the varieties. Super Napier consistently displayed a significantly lower ($p=0.018$) number of tillers compared to both CO3 and CO4 at each data recording. It ranged from 3 to 9 tillers from 3WAP to 6 WAP. This suggests a distinct difference in tillering capacity among the varieties. While CO3 and CO4 showed similar ($P>0.05$) tillering rates, Super Napier's slower tillering may indicate a different growth strategy or resource allocation pattern. Amin *et al* (2016) indicates that the Napier variety, a typical plant has 35–100 tillers, depending on the variety and season. According to earlier research, the greatest number of tillers (10.00) were seen in

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Napier grass after 56 days of planting (Sathees and Sivaranjani, 2022Sathees and Sivaranjani, 2022). Moreover, tillering influences the plant's architecture, affecting its ability to compete for resources like light and nutrients (Assuero and Tognetti, 2010.). Dense tillering can create a more robust canopy, potentially suppress weed growth and improving resource utilization efficiency.

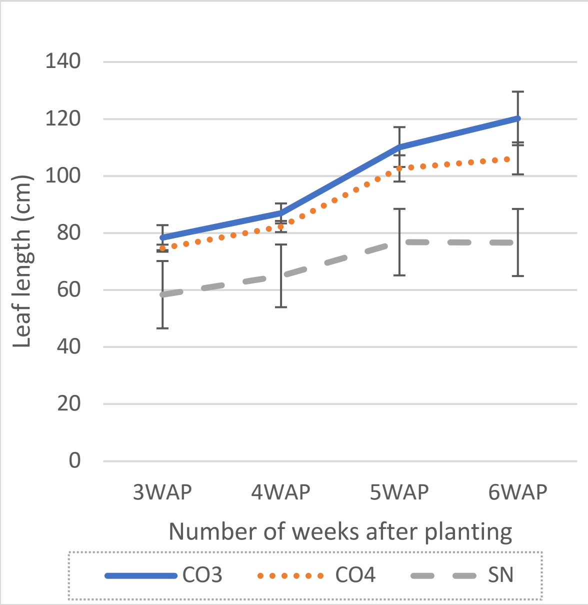

Figure 04: Variations in leaf length of fodder varieties over the six-weeks of protected house experiment

Leaf length demonstrated significant variation across the three fodder varieties during the observed growth period (Figure 04). Initially, at 3 weeks after planting (WAP), Super Napier exhibited the shortest leaf length, significantly lower than both CO3 and CO4. As the plants progressed, all varieties showed an increase in leaf length, but the magnitude of increase varied. Notably, CO3 consistently displayed the highest leaf length, reaching a peak of 120.2 cm at 6 WAP. CO4 also showed a substantial increase, though consistently lower than CO3. Super Napier, while exhibiting growth, maintained a significantly shorter leaf length throughout the experiment. The significant p values at 3 (p= 0.084) 4 (p= 0.031) 5 (0.001), and 6(p = 0.001) WAP indicate that these differences in leaf length were statistically significant, suggesting distinct varietal growth patterns. This difference in leaf length could have implications for overall biomass production and forage quality, with longer leaves potentially contributing to higher yields.

According to Goldsworthy *et al* (1974), plant's leaf area increases with leaf length, which improves the amount of feed generated as a result of efficient photosynthesis. An analogous outcome was observed in the present study. According to Mounika *et al* (2015), the CO3 leaf length measured in the eighth week (81.17cm) of maturity and the 12th week of maturity (82.26 cm were identical. Sathees and Sivaranjani (2022) have shown that Napier grass produces longer leaves, measuring 95.33 cm, 56 days after cultivation.

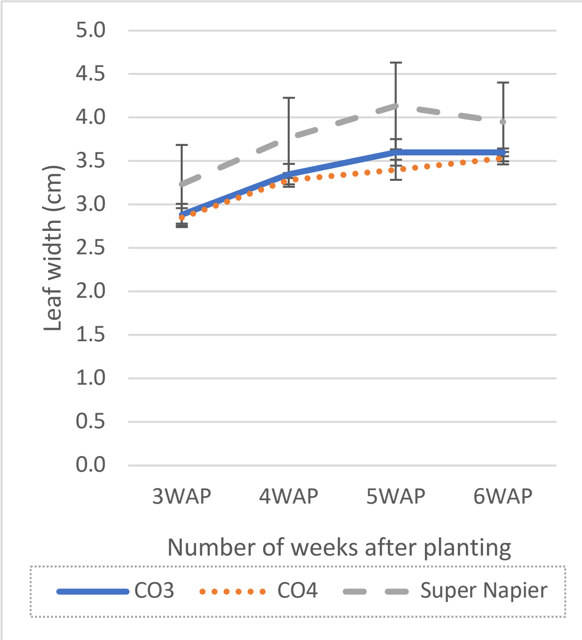

Figure 05: Variations in leaf width of fodder varieties produced over the six-weeks of protected house experiment.

In contrast to leaf length, leaf width showed relatively little variation among the three fodder varieties across the observed growth period. Although there were slight fluctuations in leaf width, particularly for Super Napier, these differences were not statistically significant. This suggests that while leaf length was a distinguishing factor among the varieties, leaf width was more conserved. All three varieties maintained a relatively consistent leaf width, ranging from approximately 2.9 cm to 4.0 cm. This uniformity in leaf width might indicate a similar physiological adaptation or resource allocation strategy for this particular trait. The lack of significant variation in leaf width suggests that it may not be a primary factor differentiating the growth patterns or productivity of these fodder varieties under the conditions of this experiment. According to Amin *et al* (2016), Super Napier leaf blades, which can grow up to 120 cm in length and 5 cm in width. The base of the leaf blades has a thick stem with a diameter of 3 cm. Further Sathees *et al* (2022) showed that Napier grass cultivated broader leaves with a width of 3.82 cm at 56 days after planting.

B. Physiological parameters of fodder varieties

1) Quantum Yield

The quantum yield, a measure of photosynthetic efficiency (Hogewoning *et al.,* 2012), can be effectively used for studying photosynthetic activity, stress detection, herbicide testing, or mutant screening, was only assessed at 6 WAP. At this stage, all three fodder varieties exhibited relatively similar ($p = 0.761$) and high quantum yields, ranging from 0.71 to 0.73. This suggests that all three varieties are equally efficient in converting absorbed light energy into biomass during this later growth stage (Table 01).

Table 01: Physiological parameters of fodder varieties

Parameters	Fodder varieties	3 WAP (Mean ± SEM)	4 WAP (Mean ± SEM)	5 WAP (Mean ± SEM)	6 WAP (Mean ± SEM)
Quantum yield	CO3				0.71 ±.0.001
	CO4				0.72 ± 0.004
	Super Napier				0.73 ± 0.007
	df				17
	P value				0.761
Chlorophyll content	CO3	43.6 ± 3.9	46.9 ± 3.6	60.6 ± 15.3	37.3 ± 3.2
	CO4	45.4 ± 4.8	42.9 ± 5.2	33.1 ± 5.0	37.1 ± 2.8
	Super Napier	33.2 ± 6.6	42.5 ± 3.7	39.5 ± 4.5	41.9 ± 3.0
	df	17	17	17	17
	P value	0.241	0.723	0.142	0.462

2) SPAD Value

Chlorophyll content, a key determinant of light absorption for photosynthesis, showed relatively stable SPAD values across the four weeks for all three fodder varieties. SPAD value of CO3 fluctuated slightly, peaking at 5 WAP, while CO4 showed a gradual decrease in SPAD value from 3 to 5 WAP, followed by a slight increase at 6 WAP. Super Napier exhibited a relatively consistent chlorophyll content across the measured period. However, chlorophyll content was non-significant at all time points. This suggests that all three varieties maintain a comparable capacity for light harvesting throughout the early to mid-growth phases.

3) Stomatal Conductance

Stomatal conductance which reflects the degree of stomatal opening and thus the rate of gas exchange (Damour *et al* 2010). For the environment, with the actual vapor flux that leaves the leaf, passes through the stomates, and exits into the surrounding air to determine stomatal conductance (mmol/ m^2s). The SC-1 could distinguish between leaves that were stressed and experiencing stomatal closure by monitoring the amount of vapor flowing through the stomates. Stomatal conductance showed a dynamic pattern across the weeks after planting. At 3WAP, Super Napier displayed the highest stomatal conductance at 3 WAP, followed by a sharp decline at 4 WAP and then a recovery at 5 and 6 WAP. Similarly, CO3 and CO4 displayed a dynamic pattern over the weeks. However, stomatal conductance was insignificant across varieties. Highest stomatal conductance was observed in Super Napier at 5WAP and the lowest was observed in CO4 at 4WAP (Figure 06).

The lower stomatal conductance in CO4 might indicate a more conservative water use strategy compared to the other two varieties. The initial high conductance in CO4 and Super Napier could be linked to rapid early growth, followed by adjustments as the plants mature and environmental conditions change (Fariaszewska et al., 2020).

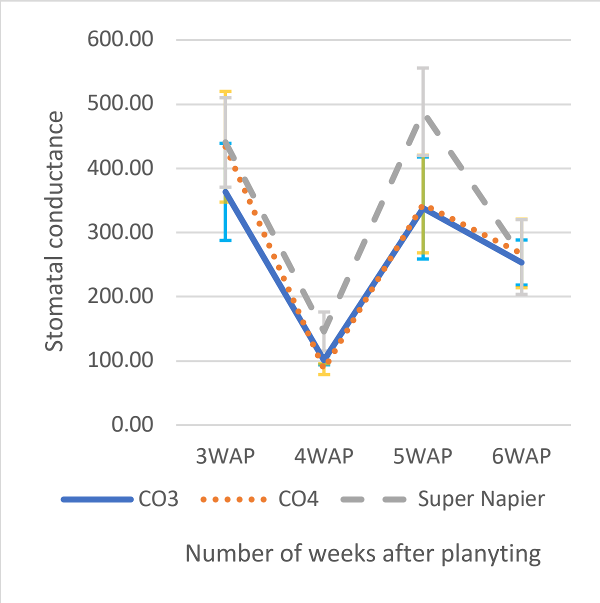

Figure 06: Variations in stomatal conductance of fodder varieties measured over the six-weeks of protected house experiment.

C. Yield parameters of fodder varieties

Table 02: Yield parameters of fodder varieties

Parameters	Fodder varieties	3 WAP (Mean ± SEM)	6 WAP (Mean ± SEM)
Fresh weight (g)	CO3	189.6 ± 15.4[a]	1611.3 ± 148.2[a]
	CO4	146.7 ± 42.0[b]	1638.3 ± 61.7[a]
	Super Napier	84.7 ± 14.9[c]	1198 ±172.8[b]
	df	8	8
	P value	0.037	0.039
Dry Weight (g)	CO3	57.7 ±7.6[a]	613.7 ± 210.8[a]
	CO4	55.3 ± 17.8[a]	505.3 ± 175.3[b]
	Super Napier	36.4 ± 2.0[b]	384.7 ± 87.8[c]
	df	8	8
	P value	0.039	0.043

Table 02 depicts the fresh and dry weight of fodder varieties at two different growth stages: 3WAP and 6 WAP. The analyzed data (Table 02) revealed significant differences in performance among the varieties. At 3 WAP, the fresh weight varied significantly (p=0.037) among the three varieties. CO3 had the highest fresh weight (189.6 g), than CO4 (146.7g) and Super Napier (84.7g). For dry weight at 3 WAP, no significant difference was observed between CO3 (57.7 g) and CO4 (55.3 g). However, Super Napier's dry weight (36.4g) was significantly lower compared to CO3 and CO4.

At the 6 WAP measurement, the fresh weight of CO3 (1611.3 g) and CO4 (1638.3 g) were not significantly different from each other. However, Super Napier's fresh weight (1198g) was significantly lower than the other two varieties. The dry weight at 6 WAP showed a significant difference across all three varieties (p = 0.043). CO3 had the highest dry weight (613.7 g) while CO4 and Super Napier had the lowest

These findings indicate that CO3 consistently produced the highest fresh and dry weight yields, demonstrating its superior biomass production compared to the other varieties, especially at 6 WAP. While CO4's fresh weight was comparable to CO3 at 6 WAP, CO3 still maintained a significantly higher dry weight, which is a crucial factor for feed quality and storage. The consistently lower performance of Super Napier in both fresh and dry weight suggests it is a lower-yielding variety under the conditions of this study.

As reported by Lakshan *et al* (2024) dry matter yield can be significantly affected by the interaction effect of variety and fertilizer. The fresh matter yield reported for CO3 in the present study was slightly higher than the values of 29.77 and 27.56 t/ha/cut reported by Chellamuthu et al. (2011) and Mounika et al. (2015), respectively, when cut at 13th week after planting in India. A study conducted by Epasinghe et al. (2012) in the wet zone of Sri Lanka has recorded an average dry matter yield of CO3 was 3.57 t/ha at 9th week of planting.

However, it is important to consider these weight parameters in conjunction with the physiological parameters (quantum yield, stomatal conductance, and chlorophyll content) to get a holistic understanding of the performance of these fodder varieties. For instance, while Super Napier had lower biomass, its photosynthetic efficiency (quantum yield at 6 WAP; Table 01) was comparable to the other varieties. This suggests that Super Napier might allocate

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resources differently or have a different growth trajectory.

IV. CONCLUSION

This study successfully evaluated the growth, physiological, and biomass characteristics of CO3, CO4, and Super Napier fodder grasses under standardized water conditions in a controlled environment. Plant height, leaf production rate (LPR), and leaf width were insignificant across varieties However, all varieties experienced a sharp decline in LPR at 4 weeks after planting (WAP) before rebounding in subsequent weeks. Despite similar photosynthetic efficiencies, which were high and insignificant across varieties at 6 WAP, the study found statistically significant differences in biomass production. CO3 and CO4 generally out-yielded Super Napier in both fresh and dry biomass at 6 WAP. Specifically, CO3 exhibited the highest dry weight at 6 WAP. CO3 also demonstrated superior leaf elongation, with the highest leaf length. In contrast, Super Napier showed distinct tillering patterns and significantly fewer tillers. These findings underscore the adaptability and high productivity potential of these fodder grasses even with a consistent water supply. The insights gained are valuable for developing more efficient cultivation practices and enhancing the resilience and productivity of fodder systems, particularly for high-yielding varieties like CO3 and CO4, in water-limited regions. Future research should explore the performance of these varieties under varying water stress levels to identify drought-tolerant genotypes and develop more precise irrigation strategies for sustainable fodder production in diverse agro-ecological zones.

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