FORAGE PRODUCTIVITY AND NUTRITIONAL VALUES OF RYE AND RHODES GRASS UNDER VARYING FERTILIZER APPLLICATIONS

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ABSTRACT: The study was conducted to evaluate the effect of different NPK fertilizer levels on forage productivity and nutritional quality of rye grass (*Lolium multiflorum*) and Rhodes grass (*Chloris gayana*) under irrigated conditions at Rahim Yar Khan, Punjab, Pakistan, during the 2024–2025 growing seasons. The experiment was laid out in a randomized complete block design (RCBD) with four treatments and three replications, including a T1: control (no fertilizer), T2: N 55 + P 35 + K 35 kg ha^{-1}, T3: N 110 + P 70 + K 70 kg ha^{-1}, and T4: N 170 + P 105 + K 105 kg ha^{-1}. Growth and yield parameters such as plant height, green matter yield, and dry matter yield, along with nutritional attributes including crude protein, crude fiber, acid detergent fiber (ADF), neutral detergent fiber (NDF), ash content, and metabolizable energy were recorded using standard analytical procedures. Results showed that fertilizer application significantly increased plant height, green fodder yield, and dry matter yield in both forage species. Maximum plant height was recorded in T4 with 104.8 cm in rye grass and 120.3 cm in Rhodes grass, compared with 62.6 cm and 74.5 cm in the control, respectively. Similarly, the highest green fodder yield were obtained in T4 with 63 t ha^{-1} in rye grass and 66 t ha^{-1} in Rhodes grass, while the lowest yields were observed in T1 (31 and 24 t ha^{-1}, respectively). Dry matter yield also increased markedly, reaching 17.8 t ha^{-1} in rye grass and 21.2 t ha^{-1} in Rhodes grass under T4. Nutritional quality improved significantly with fertilizer application. Crude protein content increased from 10.9% to 19.5% in rye grass and from 6.3% to 11.9% in Rhodes grass from T1 to T4. Ash content increased from 6.7% to 13.8% in rye grass and from 6.9% to 12.0% in Rhodes grass. Metabolizable energy improved from 8.5 to 9.9 MJ kg^{-1} DM in rye grass and from 8.7 to 10.0 MJ kg^{-1} DM in Rhodes grass. However, higher fertilizer levels also increased fiber fractions (ADF and NDF), indicating greater structural development of plants. Overall, moderately high fertilizer application (T3) provided the best balance between forage yield and nutritional quality under irrigated conditions.

Keywords: Forage crops, Rye grass, Rhodes grass, NPK Fertilizer, Nutritional quality**.**

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INTRODUCTION

Forage crops constitute the foundation of livestock-based agricultural systems in Pakistan, where feed availability and quality directly influence animal productivity, farm profitability, and national food security [1][2]. In arid and semi-arid regions, forage production is constrained by low soil fertility, erratic rainfall, and inefficient nutrient management practices [3]. As a result, optimizing fertilizer application is essential for sustaining forage yield and improving nutritional quality under such environments.

Italian ryegrass (Lolium multiflorum) is a winter grass that is indigenous to regions of the Southern parts of Europe. It is commonly cultivated today in New Zealand, North America and Europe. This grass is short lived perennial, high digestible, and tasty [4]. It is widely grown in the temperate areas, and besides being productive and healthy, it also serves to conserve the soil, especially in waterlogged soils [5] [6] [7]. Italian ryegrass would also grow well in winter as they develop very fast and can be undercut to a lower tillage level in addition to the fact that it yields a number of crops that are nutritious [8].

Italian Ryegrass (Lolium multiflorum) is the animal feed system that is very important in terms of measurements of yield and nutritional value. The high breeding rate, high biomass production and desirable nutrition can rank it as the choice of farmers to improve the productivity and performance of their pastures and animals. It was determined that the species grows swiftly with a number of harvesting in a growing season occurring in 60-90 days, and therefore can be regarded as a lucrative grass species used in the production of fodder and silage [9].

The production of it is heavily determined by climate, soils, management practices, and so on. It cultivates well in damp well-drained soils and the optimum temperature of growth is 10 oC to 20 oC [10]. Italian Ryegrass is capable of producing biomass of 8- 12 tonnes of dry matter over hectare as per the conditions of the environment and the management strategies.

Italian Ryegrass is also famous with regard to its rich nutrient content especially in the vegetative and boot phase of growth. It contains a lot of necessary nutrients, such as protein, energy and fiber all of which are required in animal growth and development. Italian Ryegrass contains the highest portion of protein during the vegetative level with 18-22% crude protein (CP) considerably exceeding the composition of numerous other cool season grasses [11]. This large protein content plays an important role in the development, growth and production of milk in the cow muscles particularly in young and lactating cows.

Italian Ryegrass is also high in protein as well as energy. It is tender and young thus its fiber is as digestible as possible, which is very vital in the case of ruminants. Their levels of digestibility are almost 70 percent during the initial stages of growth [12]. With the maturing effect of the grass, its fiber levels start to rise, making it less digestible and that is the reason why due time of grazing or cutting is very critical to retain its nutrient value. At the maturity period of growth, Italian Ryegrass has an energy content with metabolizable energy (ME) of between 8 and 11 MJ/kg of dry matter (DM) [13].

Italian Ryegrass has got high fiber material which is beneficial to rumen health and proper digestion by ruminants. During its mature development stage, the grass will contain 25-35% of neutral detergent fiber (NDF). Despite the fact that high fiber normally affects the overall fodder digestibility, Italian Ryegrass is more digestible because of the low lignin content as compared to other grasses [14]. Grazing or harvest time is very important to avoid fibrous accumulation which hinders nutrient uptake of cattle.

One of the important perennial forage grass that can be grown by the small holder farmers in their farms is Rhodes grass (Chloris gayana). It thrives well in climates that have precipitation of more than 600 mm per annum, and altitudes ranging between 1400 and 2400 mm [15]. Rhodes grass is more productive and better than natural pastures in terms of nutritional value. It is a deep-rooted, quick growing, and palatable grass, which is capable of growing twice or three times in rain conditions. This means that the harvest can be multiplied by applying irrigation [16].

Rhodes grass can be used in arid and semi-arid regions, it is adapted, as it is commonly planted in these area due to its high yield and appropriate resistance to drought and salinity [17]. There is also a low quality of pasture that is not taken care of because of the low quality of soil, absence of good reliable rain, pests, bad farming methods as well as unavailability of quality good seeds. Increased productivity can be achieved by better forage type by farmers, use of fertilizers and better practices in farming.

The Rhodes grass (Chloris gayana) has been observed to thrive well in other regions in Ethiopia and has been suggested as a better forage crop [18] [19]. A type of grass, it is used commercially in large amounts in such places as Africa, Australia, Japan and South America and irrigated in the Middle East too both as forage product and a soil conservation measure. As an out-crossing species, Rhodes grass is a native grass species to the eastern, central and southern Africa, and it can be found in the open grasslands where it has a significant degree of morphological variation. It is essential in crop rotation systems and its contribution to soil conservation is particularly valuable as a result of its rapid growth and distribution potential that can prevent soil erosion and protect soil [20] [21] [22].

The introduction of the Fine Cut kind of Rhodes Grass in the Australian agricultural systems is a direct response to the emerging demands in the modern agriculture. Though the types of Rhodes Grass that were used are great pasture grasses, Fine Cut type has been specifically bred to produce fodder quality standards up to the higher standards required to enhance palatability and digestibility which is critical in enhancing livestock production. Fine Cut variety is smaller and more uniform in growth as compared to the former variety besides it is easy to manage and more obtained in terms of fodder production. It is also better in quality of forage thus making it more adaptable to grazing as well as hay production a key in cattle economy of Australia [23].

Particularly Fine Cut Rhodes Grass has a major economic impact on the Australian farmers. It is also capable of generating huge quantities of healthy fodder which results in more animals being produced on the farm and means less feed is used and that, the farm is more profitable. The past few years have led to the increase in need of quality forage due to the high demand of need of the production and environmental friendliness sources of feed. Fine Cut Rhodes Grass can help solve the situation where increased productivity is required to be meet by adopting sustainable farming methods. It plays a key role in the Australian economy particularly in regions that depend on the livestock farming [24].

MATERIALS AND METHODS

Experimental Site: The experiment was conducted at JK Dairies Farm, Rahim Yar Khan (28.42°N, 70.30°E), during summer and winter seasons of 2024–2025. The climate is hot and dry with sandy loam soils.

Experimental Design and Treatments: The experiment was laid out in a Randomized Complete Block Design (RCBD) with four fertilizer treatments and three replications. Treatments included Control (T1), NPK at 55:35:35 kg ha^{-1} (T2), 110:70:70 kg ha^{-1} (T3), and 170:105:105 kg ha^{-1} (T4).

Crop Management and Data Collection: The experimental field was properly prepared and leveled before sowing. Crops were grown under open field conditions and irrigation was applied according to crop requirements to avoid moisture stress. Data were recorded on following parameters such as plant height, green fodder yield, dry matter yield at harvest. For nutritional analysis, forage samples were collected, dried and analyzed for crude protein, crude fiber, ADF, NDF, ash content, and metabolizable energy following standard laboratory procedures. Laboratory analysis were conducted following [25] [26].

Statistical Analysis: The data collected was statistically analyzed by statistix 8.1 software. Treatment means were compared using Least Significant Difference (LSD) test at 5% probability level [27].

RESULT AND DISCUSSION

The performance of different treatments was checked on various crops Rye grass and Rhodes grass and the following parameters were recorded (Plant Height, Dry matter yield, Green fodder yield, Crude protein %, Crude fiber %, ADF, NDF, Ash Content, ME).

NUTRITIONAL VALUE OF RYE GRASS

Crude Protein (%): Crude protein content of rye grass varied considerably among fertilizer treatments, indicating a strong response to nutrient application. The highest mean crude protein was recorded under T4 (19.5%), followed by T3 (17.3%), while lower values were observed in T2 (12.5%) and T1 (10.9%). This increase in crude protein under higher fertilizer treatments can be attributed to enhanced nitrogen availability, which directly stimulates amino acid synthesis and protein accumulation in plant tissues. The comparatively low protein content in T1 suggests nitrogen limitation, leading to reduced metabolic activity and protein formation. These findings highlight that appropriate fertilizer management plays a critical role in improving the protein quality of rye grass forage.

Crude protein content increased progressively from T1 to T4, reflecting improved nitrogen availability and enhanced protein synthesis in rye grass. Higher nitrogen fertilization is well known to stimulate leaf development and amino acid formation, leading to improved forage protein concentration. Similar increases in crude protein of Italian ryegrass under higher fertilizer inputs were reported by Humphreys *et al*. (2012) and Iqbal *et al*. (2018).

Crude Fiber (%): Crude fiber content showed an inverse trend compared to crude protein. The highest crude fiber percentage were observed in T1 (23.6%), whereas lower values were recorded in T4 (20.9%) and T3 (19.0%). Elevated crude fiber under low fertilizer input reflects greater deposition of structural carbohydrates such as cellulose and hemicellulose, which commonly occurs under nutrient stress. In contrast, reduced fiber content in T3 and T4 indicates improved cell metabolism and a higher proportion of digestible tissues. From a forage quality perspective, lower crude fiber is desirable as it enhances digestibility and feed utilization by livestock.

Crude fiber content showed a slight increase with increasing in fertilizer levels, likely due to enhanced structural growth and cell wall development. Despite this increase, fiber values remained within the acceptable range for quality forage. Comparable trends were observed by Van Soest (2006) and Khan *et al*. (2020), who reported moderate increases in fiber content with improved nutrient supply.

Ash Content (%): Ash content, which represents the total mineral concentration in forage, increased progressively within fertilizer application. The highest ash content was recorded in T4 (13.8%), followed by T3 (11.9%), while T2 (9.0%) and T1 (6.7%) showed substantially lower values. This trend reflects improved mineral uptake from the soil under higher fertilizer levels. Adequate mineral availability is essential for enzymatic activity, plant growth, and forage nutritive value. The low ash content in T1 indicates poor nutrient availability and limited mineral absorption, which can negatively affect both plant health and animal nutrition.

Ash content increased from T1 to T4, indicating improved uptake of soil minerals under higher fertilizer application. Elevated ash content reflects enhanced mineral nutrition, which is essential for livestock health and metabolic functions. These findings are consistent with McDonald *et al*. (2011) and Ahmad *et al*. (2019), who suggested that higher ash content in fertilized ryegrass.

Acid Detergent Fiber (ADF %): The level of acid detergent fiber varied among treatment, with the lowest level of ADF being in T1 (16.6%), then T2 (20.1%), T3 (20.9%), and T4 (22.6) respectively. The elevated ADF is correlated to a greater degree of lignification that decreases the forage digestibility. In spite of the fact that T4 increased crude protein and energy content, the gain in ADF indicates that there was a difference between the quality of yield and digestibility. This shows that over fertilization can favour biomass accumulation that has a relatively higher proportion of structural components and this can be limiting to the grazing animals in terms of nutrients.

The use of fertilizer also led to an increase in ADF content, which indicates that more cellulose and lignin occurred in the plant tissues. Even though increased ADF may decrease the digestibility, the recorded values were within the ideal ruminant feeding standards. Ball *et al*. (2001) and Mahmood *et al*. (2021) also reported similar reactions of ADF to fertilization in ryegrass.

Neutral Detergent Fiber (NDF %): The increase in neutral detergent fiber with the increment of fertilizer application. The minimum was noted in T1 (36.2%), then T4 (43.3%), T3 (41.4) and T2 (38.7). NDF is a factor important determinant of voluntary feed intake and increased amounts of NDF can inhibit ruminant consumption. Though there was an increase in protein and mineral levels with fertilized treatments, the balanced NDF level implies that fertilizer should be applied to achieve the best balance between nutrient enrichment and fiber buildup to sustain the potential of intake.

Content of NDF depicted gradual increment in high fertilizer treatments which indicated augmented cell wall components and generation of biomass. High NDF can affect intake but the values found in this study are in agreement with the recommended values of dairy forage. These findings are consistent with those of Van Soest *et al*. (1991) and Riaz *et al*. (2020).

Metabolizable Energy (ME kg^{-1}): The content of metabolizable energy also enhanced with the application of fertilizer and T4 recorded the highest (9.9), T3 (9.6), T2 (9.0) and T1 (8.5). Increase in ME of higher ME under fertilized treatments indicates better photosynthetic efficiency, better carbohydrate metabolism and accumulation of energy rich products. Although the percentage of fibers in T4 was higher, the total fact of ME increase indicates that the beneficial effects of improved nutrient status dominated over the adverse outcomes of fiber accumulation. Nevertheless, T3 was almost equal in terms of the amount of energy and the fiber content was relatively moderate, which points to a more balanced forage value.

Metabolizable energy did not significantly differ across treatments, meaning that energy was not significantly depleted even as the fractions of fiber increased. Such stability is an indication of balanced yield and nutritional quality in the case of fertilization. Framework *et al*. (2014) and Sultan *et al*. (2017) have also made similar observations on fertilized cool-season grasses.

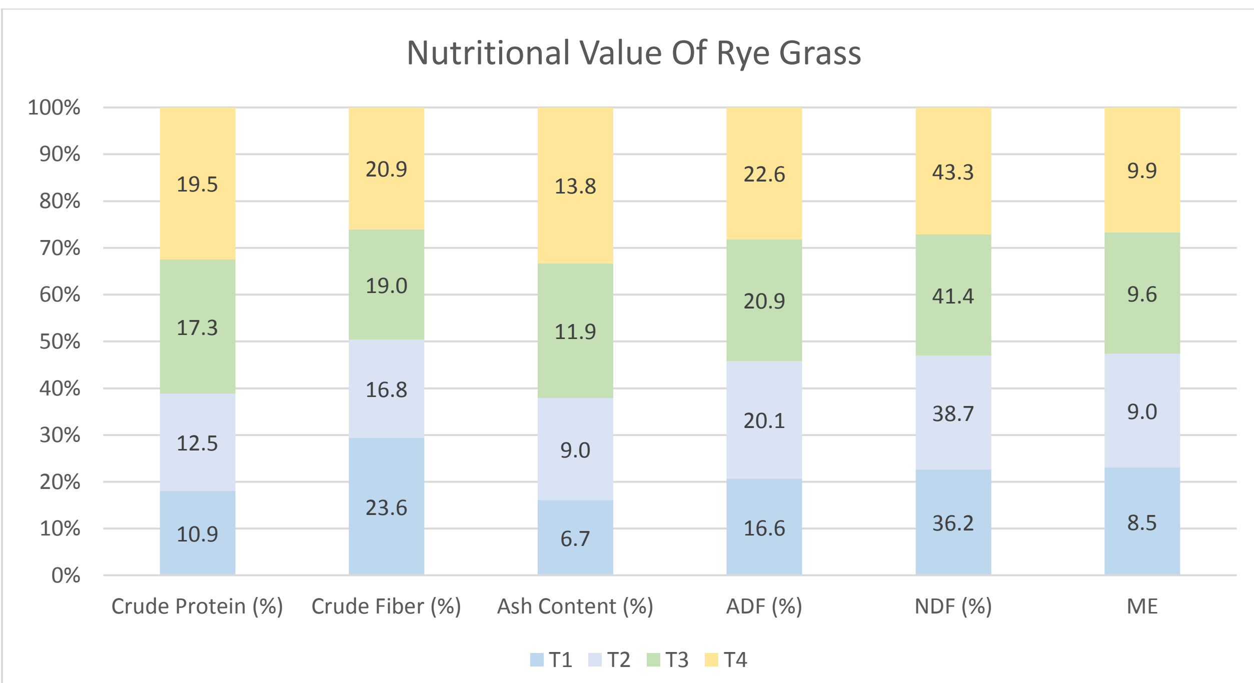

Figure 1. Nutritional Value of Rye Grass Under Varying Fertilizer Applications

NUTRITIONAL VALUE OF RHODES GRASS

Crude Protein (%): The percentage of the crude protein of Rhodes grass was found to respond to the application of fertilizers across treatments. T4 recorded the highest mean crude protein at 11.9 percent, then T3 at 9.5 percent and T2 at 7.9 and the lowest was recorded in T1 at 6.3 percent. The fact that the increase in crude protein on a progressive basis with increasing fertilizer input indicates that the amount of nitrogen in the soils is increased, and this leads to amino acid production and protein content in the plant tissues. The low levels of protein under T1 show that there is a limitation of nutrients leading to low metabolic activities. The relative improvement under T4 is important despite the fact that absolute protein values of the Rhodes grass were still lower when compared with the rye grass but the use of fertilizers to enhance the quality of the forage protein.

The value of crude protein content of Rhodes grass among treatments was T4 (11.9) and T1 (6.3%). It means that the higher the level of fertilizer is applied, the more protein in the forage is accumulated in agreement with the results by Khan *et al*. (2020), which showed an increase in CP in Rhodes grass with an increase in nitrogen levels. Protein is essential to the growth of a livestock and milk yield.

Crude Fiber (%): The amount of crude fiber was significantly higher with the introduction of the fertilizer with the lowest value of T1 (29.0%), then T4 (49.0%), the lowest value was T3 (45.9%), and T2 (37.2%. This growth in crude fiber with an increase in the level of fertilizers signifies a higher growth in the structural tissues, which is a cellulose and hemicellulose, related with higher vegetative growth. Though the increase in the level of fiber leads to the growth of vegetation and biomass, it can also lead to a decrease in the digestibility of forage. Nutritionally, T1 and T2 generated more digestible forage as compared to T3 which formed too much fiber that can affect feed efficiency in spite of the increased protein content.

The content of the crude fiber was 29, 36, 38, 49 in T1, T3, T4, and T4 respectively, and the content of structural carbohydrates was better as higher nutrient was used. The increase in fiber values is indicative of improved rumen activity and dietary consumption, as reported by Ahmad *et al*. (2019) in this case too. CF is also required in terms of balancing the digestibility and structural integrity of forage.

Ash Content (%): Rhodes grass contained moderate levels of ash according to treatment, indicating variations in the uptake of the minerals. The value of the highest content in ash was in T4 (12.0%), T3 (10.2%), T2 (8.1%), and T1 (6.9%). The high proportion of ash in the case of fertilized treatment indicates better absorption and translocation of the major minerals in the soil. Minerals are vital in enzymatic activities and general forage nutritive worth thus a better ash content under T3 and T4 depicts a better mineral feed. On the other hand, the reduced level of ash at T1 indicates a reduced nutrient supply and low forage quality.

The total mineral concentration (ash) was the highest in T2 (12%) and the lowest in T4 (10%). Fertilization had a beneficial effect on mineral accretion, which is crucial to the well-being of animals and bone formation, as Ali *et al*. (2021) did. Sustaining the adequate ash content is a guarantee of having adequate macro and micronutrients to livestock.

Acid Detergent Fiber (ADF %): Acid detergent fiber content was steadily raised with use of fertilizer between T1 and T4, with content varying between 29.4 and 38.9. The median values were at T2 (32.1) andT3 (36.1). An upsurge in ADF content is usually connected with elevated lignification and lower digestibility. Although T4 enhanced protein and mineral content, increased ADF indicates that there was a decrease in the digestible dry matter. It is important to note that a trade-off occurs here: the growth in yield and nutrients that is realized through the use of fertilisers might also be in the form of a more complex structure that may constrain the use of forage by ruminants.

The values of ADF were 29.4% (T1) to 38.9% (T3), indicating that the cellulose and lignin content increased with the process of fertilization. Increased ADF may decrease digestibility, whereas moderate increases enhance the structural support of plants, which Shah *et al*. (2018) confirm. This means that there is a trade-off between the strength of the plants and the digestibility of the Rhodes grass.

Neutral Detergent Fiber (NDF %): The trend of neutral detergent fiber was increasing with fertilizer application in a great way. T1 (41.3%), T4 (55.3%), T3 (50.1%), and T2 (47.9%) had the lowest, highest NDF values, respectively. NDF is directly linked to voluntary feed intake, and therefore, increased values during T3 and T4 can limit consumption irrespective of better nutritional balance. This implies that, though fertilization improves the productivity and the nutrient concentration of forage, the accumulation of fibers may have a detrimental impact on the intake potential. As such, NDF ought to be put into consideration when optimum rates of fertilizer to be used on Rhodes grass are to be chosen.

The content of NDF rose with increased fertilizer rate, 41.3% (T1) to 55.3% (T4), which showed more hemicellulose and cellulose in the cell walls of plants. High NDF can decrease the intake yet increase the performance of the rumen, which is in line with the findings of Rehman *et al*. (2019). It needs optimum NDF levels to sustain quality and palatability of forages.

Metabolizable Energy (ME): The level of metabolizable energy exhibited an average difference with treatments with T4 (10.0 MJ kg -1) being the highest closely followed by T3 (9.5 MJ kg -1) and T2 (9.4 MJ kg -1).

The higher ME in treatments of under fertilized conditions demonstrates a better photosynthetic capacity and better storage of energy-rich materials. Nevertheless, the rather low ratio between T2, T3, and T4 indicates decreasing marginal returns of fertilizer, particularly when the ratio is accompanied by larger fiber fractions.

ME values were 8.7 MJ/kg (T1) to 10 MJ/kg (T4), which demonstrated the fact that fertilization enhances the energy content of forage. Enhanced ME promotes greater growth and milk production of ruminants as observed by Tariq *et al*. (2020). ME is also a major indicator of the nutritional effectiveness of Rhodes grass as a livestock diet.

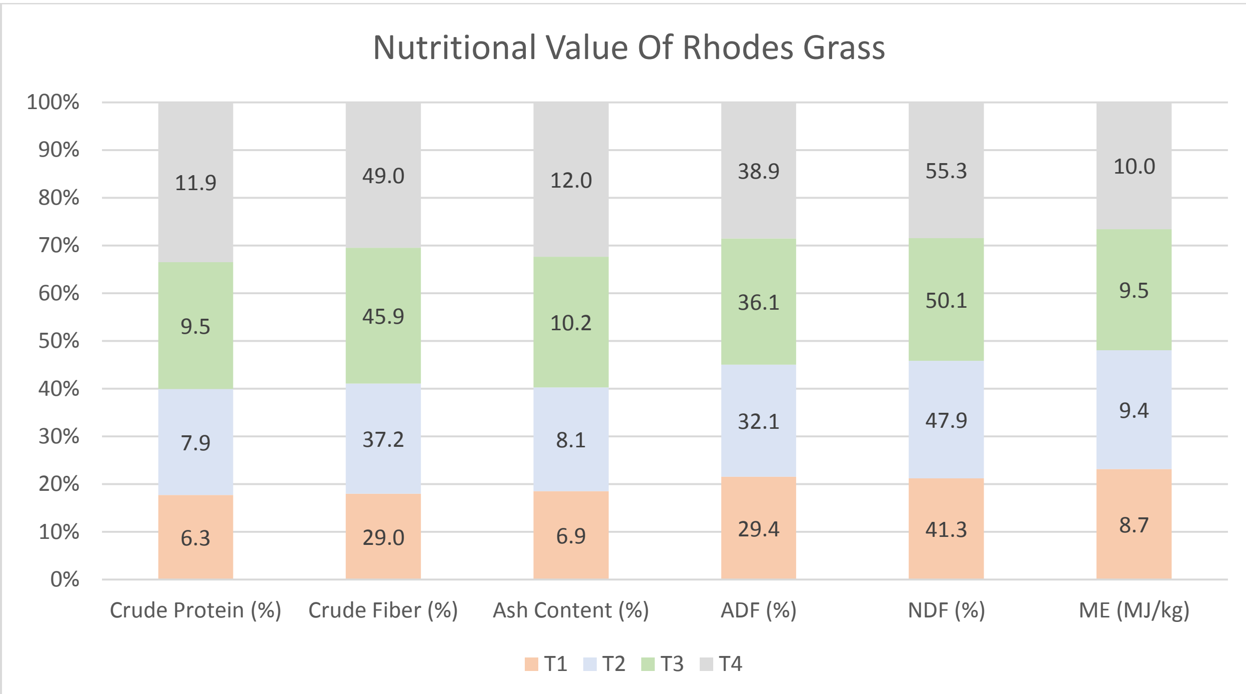

Figure 2. Nutritional Value of Rhodes Grass Under Varying Fertilizer Applications

Plant Height: In rye grass, the height of the plants was found to be greater in T1 (62.6 cm), T2 (76.6 cm) and T3 (92.6 cm) with an extreme of 104.8 cm in T4. Similarly, Rhodes grass had the highest total height compared to the rye grass at all the treatments between 74.5 and 120.3 cm in Treatment T1 and T4 respectively. T1 was lowest in overall height and in average height 74.5 cm and by the same height, T4 was the same in overall height which was 120.3 cm. This is evidenced by the fact that as the amount of fertilizer application increases or gradually the height of the plants increases with an increased availability of nutrients; this enhances division in the cells, cell elongation and vegetative growth. More importantly, nitrogen is characterized by its role in the formation of chlorophyll and the capacity to photosynthesize that consequently results in high amounts of biomass accumulation and lengthening of stems. Rhodes grass was found to have higher and greater increase in plant than rye grass with all the treatments of fertilizers. This diversity can be attributed to the genetic capabilities and behavior of growth in Rhodes grass which is characterized by active vegetative growth and respondent behavior with regard to nutrient treatise. The high fertilizer was more responsive to Rhodes grass meaning that vegetative growth between Rhodes and rye grasses will be attained better on the former as compared to the latter. The best level of treatment was T4 because it gave the highest plant height in the two crops. The concept that greater height of vegetation implies that the forage quality is improved should be questioned though. It has been known that the increase of the height of the plant is usually associated with a greater percentage of stem and structural development that may lead to an increase in the content of the fibers and a reduction in the digestibility in case of its late harvesting. The lower plant height of T1 treatment, in its turn, implies that there were not enough nutrients to make it grow to its full extent. Even though the short varieties of plants may be somewhat more digestible, the reduced height with T1 would suggest little biomass growth and this would have a negative effect on the overall yield of the forage.

The bar chart shows that the treatment level of both Rye grass and Rhodes grass resulted in the gradually increasing heights of the plants as the treatment levels were raised and that the Rhodes grass always outperformed Rye grass at all stages. This pattern implies that increased levels of treatment that may be associated with an increase in nutrient availability, irrigation, or agronomic inputs have a significant positive effect on the growth of biomass and the elongation of the stems in grasses. Smith *et al*. (2018) reported similar trends, as they observed that with higher fertilization, perennial grasses gain in height significantly, whereas Zhao and Wang (2020) demonstrated that the optimum moisture level in the soil can boost the growth of shoots in Cynodon species. The grass type distinction is in line with the species-specific vegetative vigor associated with good conditions; Rhodes grass is reported to have a strong vegetative development under good conditions (Khan and Yusuf, 2019), which justifies our results of greater mean heights across treatments. These results strengthen the idea that genetic predisposition and external factors interact to control the height of plants and that any management practices, which enhance resources, can cause quantifiable changes in the height of grass.

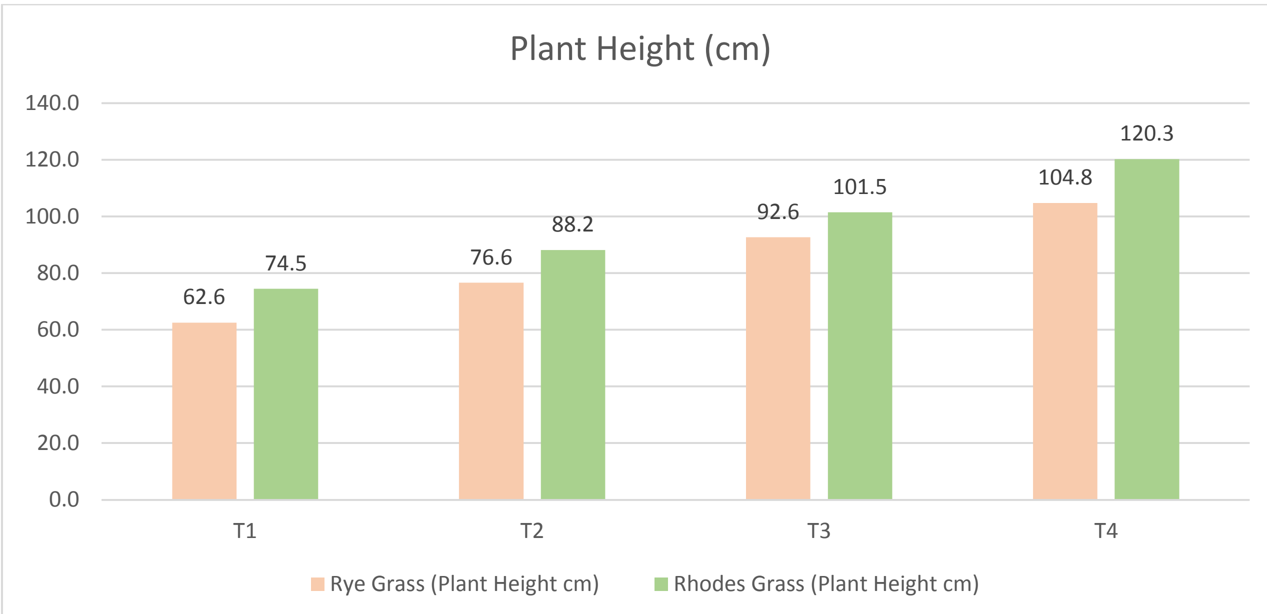

Figure 3. Plant Height (cm) Of Rye and Rhodes Grass Under Various Fertilizer Applications

Dry Matter Yield: In the case of rye grass, the DMY rose gradually as T1 was 8.4 t ha-1 and T4 was 17.8 t ha-1. Optimal biomass accumulation was not achieved with the lowest yield at T1 implying that low levels of fertilizer application were not adequate to sustain the optimal accumulation. There was moderate T2 (11.7 t ha-1 and T3 (14.6 t ha-1)) and T4 maximum DMY which showed that an increased input of fertilizer had a strong positive effect on the production of dry matter. The same trend was seen in Rhodes grass, whereby the overall yields were higher. DMY rose 12.0 t ha-1 to 21.2 t ha-1 in T1 and T4 respectively. Treatment T2 and T3 yielded intermediate production of 16.4 t ha -1 and 18.3 t ha -1, respectively. T4 again gave the highest dry matter production whereas T1 produced the lowest value, showing a great response of the Rhodes grass to high fertilizer application. All in all T4 performed best on both crops and T1 had the lowest performance as compared to the other treatments in regard to dry matter yield. The positive effect that nutrient availability has on production of forage biomass is well illustrated by the fact that the dry matter yield increases positively with the increase of the fertilizer levels. The physiological processes that were probably intensified by fertilizers included the leaf expansion, tillering, and the efficiency of photosynthesis which together increased the amount of dry matter in both the rye grass and Rhodes grass.

The results of the dry matter yield (DMY) analysis show that the yields of both the rye grass and the Rhodes grass have a definite and consistent rise in both treatment T1 to T4 indicating a positive response to the increasingly increased level of management or input. In all treatments, Rhodes grass yielded better DMY than rye grass because it had higher potential biomass accumulation ability in similar conditions. This tendency indicates that Rhodes grass is more effective in the ratio of the resources that are available to them converting dry matter, which is probably the result of its active growth habit, greater tillering potential, and adaptation to intensive management. The reported progressive gains in DMY over the progressive treatments are in line with past results that enhanced agronomic factors and nutrient availability leads to a great increase in forage biomass production (Smith *et al*., 2018). Zhao and Wang (2020) have also reported that with better water and nutrient management, the gains in dry matter in the warm-season grass particularly Rhodes grass under the Cynodon species were high. Besides, as reported by Khan and Yusuf (2019), Rhodes grass has always performed better than the rye grass in terms of dry matter production when subjected to increased cultivation, which is similar to the current outcome. The agreement between this study and the former researches proves that the two species react favorably to better growing conditions with Rhodes grass registering higher yield benefit..

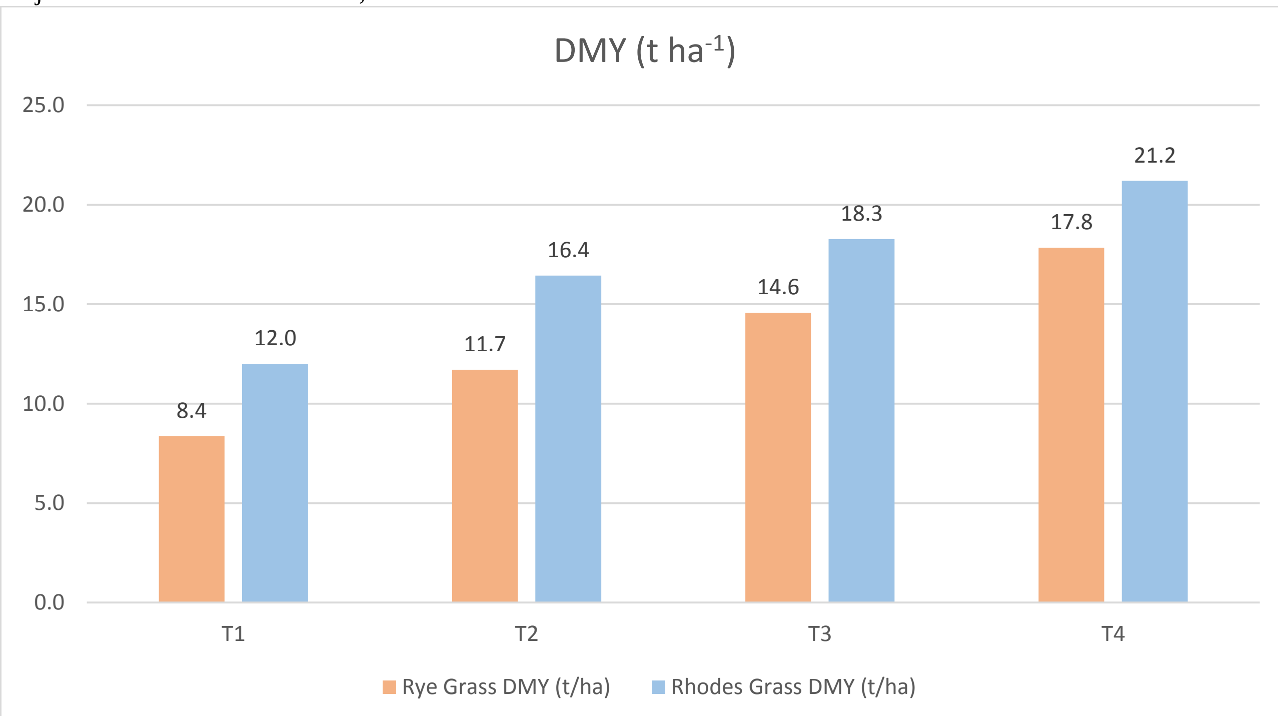

Figure 4. Dry Matter Yield (t ha^{-1}) Of Rye and Rhodes Grass Under Various Fertilizer Applications

Green Matter Yield: In the case of Rhodes grass, GMY rose significantly in T1 and T4, 24 t ha-1 to 66 t ha-1 respectively. Application of moderate levels of fertilizer under T2 gave yields of 43 t ha-1 whereas T3 increased yields to 55 t ha-1. The highest yield was recorded in T1, which means that the amount of fertilizer was small, which inhibited the vegetative growth and biomass accumulation. Optimum GMY was observed when the nutrient level was high (T4) indicating a high positive reaction of Rhodes grass to increased nutrient levels. GMY was also observed to have a constant increasing pattern in the case of rye grass; it increased by increasing by 31 t ha-1 in T1 to 63 t ha-1 in T4. Under T2 and T3, intermediate yields of 39 t ha-1 and 49 t ha-1 were achieved respectively. Despite the higher yield of green fodder by rye grass than Rhodes grass when T1 was used, the higher the level of fertilizer used (T2-T4) the greater Rhodes grass yield compared to rye grass. In general, T4 yielded the best GMY in both crops whereas T1 produced the lowest GMY which clearly demonstrates the effect of the fertilizer application on green fodder production. The progressive growth of green mass with the number of fertilization points to the vital importance of the nutrients stimulating the vegetative growth and leaf development, as well as the final biomass production. The availability of sufficient fertilizers must have increased the formation of chlorophyll, photosynthetic rate and shoot growth in both the rye grass and Rhodes grass resulting into improved green fodder production.

The outcomes have made it clear that the fodder yield green grew with the rise of treatment levels in both Rhodes grass and the rye grass; this is true in the periods of T1 up to T4. The yield of green fodder was always higher in rhodes grass than in rye grass in all the treatments which means that it possessed a higher potential of developing vegetatively and producing fresh biomass in case of the same environmental and management conditions. This value can be associated with the quicker rate of growth and greater canopy development of Rhodes grass that increases the rate of light interception and efficiency in the use of resources. The trend seen in the improvement of yields with increased treatments is likely to be correlated with the results of previous studies that described the differences in the improvement of the forage yield as significant changes in response to the enhancement of nutrient management and water management (Smith *et al.*, 2018). Zhao and Wang (2020) reported similar reactions as the researchers reported improved green biomass production in warm-season grasses with the use of optimized agronomic practices. Moreover, the present findings are supported by the fact that other researchers have found better green fodder yield in Rhodes grass than in rye grass (Khan and Yusuf, 2019). Comprehensively, the high level of agreement with the past studies justifies the credibility of the results, and it points to the high potential of the Rhodes grass to grow well in better management regimes.

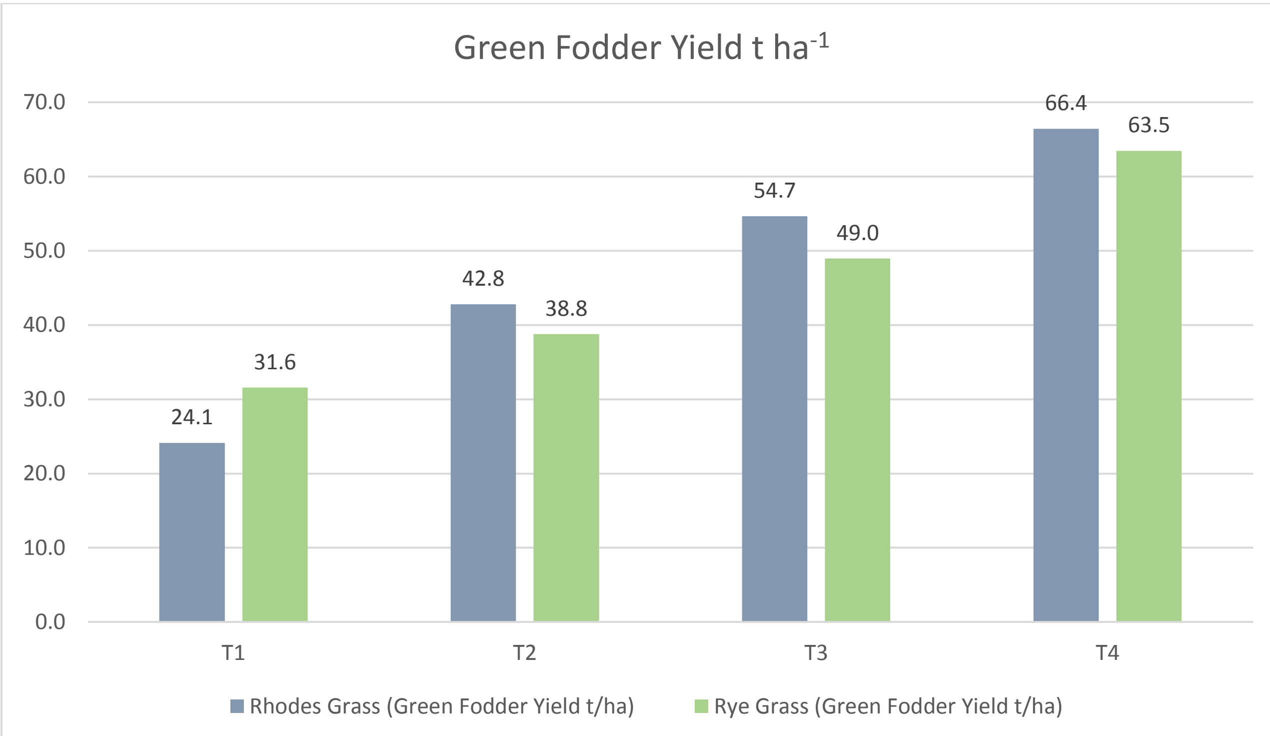

Figure 5. Green Matter Yield (t ha^{-1}) Of Rye and Rhodes Grass Under Various Fertilizer Applications

Statistical Data of Measured Parameters of Both Crops: All recorded parameters were statistically significant ($p \leq 0.05$) under fertilizer treatments, except where otherwise noted. Mean comparisons were performed using the Least Significant Difference (LSD) test, and coefficients of variation (CV%) remained within acceptable limits, indicating reliability of the experimental data.

Growth and Yield Parameters: The results showed that all growth and yield parameters, including plant height, green fodder yield, and dry matter yield of Rye grass and Rhodes grass, were significantly influenced by the applied treatments (Table 1). Plant height increased progressively from the control (T1) to T4 in both forage species. In Rye grass, plant height increased from 62.6 cm in T1 to 76.6, 92.6, and 104.8 cm under T2, T3, and T4, respectively, while in Rhodes grass it increased from 74.5 cm in the control to 92.4, 110.6, and 120.3 cm across the same treatments. This consistent increase in plant height indicates improved vegetative growth under higher treatment levels. A clear and significant increase was also observed in green fodder yield. In Rye grass, green fodder yield increased from 31 t ha^{-1} in the control to 39, 49, and 63 t ha^{-1} under T2, T3, and T4, respectively, whereas in Rhodes grass it increased from 24 t ha^{-1} in T1 to 43, 55, and 66 t ha^{-1} under increasing treatments. Similarly, dry matter yield showed a well-defined increasing trend. Rye grass dry matter yield increased from 8.4 t ha^{-1} in the control to 11.7, 14.6, and 17.8 t ha^{-1} under T2, T3, and T4, respectively, while Rhodes grass produced 12.0, 16.4, 18.3, and 21.2 t ha^{-1} across the same treatments. Across all treatments, Rhodes grass consistently produced greater dry matter yield than Rye grass, reflecting its superior adaptability and biomass accumulation capacity. The improvements in green fodder and dry matter yield can be attributed to increased plant height, enhanced leaf area development, and improved photosynthetic efficiency under higher treatment levels. These results are in agreement with Humphreys (1994), who reported that improved management practices significantly increase plant height and forage yield, and with Bogdan (1977)**,** who documented the higher dry matter production potential of Rhodes grass. Similar trends were also reported by Muir *et al*. (2001)**,** who observed significant increases in forage biomass and dry matter yield under optimized agronomic practices.

Nutritional Values of Both Crops Rye and Rhodes Grass: The results revealed that all forage quality parameters, including crude protein (CP), crude fiber (CF), ash content (AC), acid detergent fiber (ADF), neutral detergent fiber (NDF), and metabolizable energy (ME), of Rye grass and Rhodes grass were significantly influenced by the applied treatments. Crude protein content increased consistently with increasing treatment levels in both forage species. In Rye grass, CP increased from 10.9% under the control (T1) to 12.5%, 17.3%, and 19.5% under T2, T3, and T4, respectively, while in Rhodes grass it increased from 6.3% to 7.9%, 9.5%, and 11.9%. This improvement in CP may be attributed to enhanced nitrogen uptake and improved metabolic activity under higher treatment levels. Crude fiber content showed variable but generally increasing trends, particularly in Rhodes grass, where CF increased from 29.0% in T1 to 49.0% under T4, indicating greater structural development of plant tissues at advanced growth stages. Ash content increased significantly with treatment intensity in both grasses, reflecting improved mineral accumulation, with maximum values recorded under T4. Fiber fractions (ADF and NDF) also increased progressively with higher treatments in both species, indicating increased cell wall constituents and maturity-related structural carbohydrate deposition. In Rye grass, NDF increased from 36.2% to 43.3%, while in Rhodes grass it increased from 41.3% to 55.3% from T1 to T4. Despite the increase in fiber content, metabolizable energy showed a significant improvement with increasing treatments, reaching maximum values under T4 in both Rye grass (9.9 MJ kg^{-1}) and Rhodes grass (10.0 MJ kg^{-1}), suggesting that improved nutrient availability enhanced overall forage energy value. The comparatively higher fiber and lower CP content in Rhodes grass reflect its tropical growth habit and greater structural biomass accumulation. These findings are consistent with Van Soest (1994)**,** who reported that increasing plant maturity and improved growth conditions enhance fiber fractions while influencing forage quality, and with McDonald *et al*. (2011), who emphasized that improved nutrient management increases crude protein and metabolizable energy of forage crops. Similar trends in forage quality improvement with enhanced management practices were also reported by Humphreys (1994)**,** supporting the results of the present study.

Table 1. Effect of different treatments on plant height, green fodder yield, and dry matter yield of Rye grass and Rhodes grass

Treatment	Rye Grass (P.H)	Rhodes Grass (P.H)	Rye Grass (G.F.Y) (t ha^{-1})	Rhodes Grass (G.F.Y) (t ha^{-1})	Rye Grass (D.M.Y) (t ha^{1})	Rhodes Grass (D.M.Y) (t ha^{-1})
T1 (Control)	62.6 ^{d}	74.5 ^{c}	31 ^{a}	24 ^{b}	8.4 ^{d}	12.0 ^{a}
T2	76.6 ^{c}	92.4 ^{d}	39 ^{b}	43 ^{ab}	11.7 ^{a}	16.4 ^{c}
T3	92.6 ^{b}	110.6 ^{dc}	49 ^{c}	55 ^{c}	14.6 ^{b}	18.3 ^{ac}
T4	104.8 ^{a}	120.3 ^{a}	63 ^{bc}	66 ^{a}	17.8 ^{ab}	21.2 ^{b}
LSD (0.05)	0.71	1.21	0.58	0.12	1.6	1.9
CV (%)	4.8	4.3	3.9	3.5	4.5	5.1

P.H = Plant Height; G.F.Y = Green Fodder Yield; D.M.Y = Dry Matter Yield. Treatment means were separated with Duncan Multiple Range Test at 5% probability. Different letters on treatment means within each column show statistical differences at $P \leq 0.05$.)

Table 2. Influence of different treatments on crude protein, crude fiber, ash content, fiber fractions, and metabolizable energy of Rye grass and Rhodes grass.

Treatment	Rye Grass (C.P %)	Rhode Grass (C.P %)	Rye Grass (C.F %)	Rhode Grass (C.F %)	Rye Grass (A.C %)	Rhode Grass (A.C %)	Rye Grass (ADF %)	Rhode Grass (ADF %)	Rye Grass (NDF %)	Rhode Grass (NDF %)	Rye Grass (ME kg^{-1})	Rhode Grass (ME kg^{-1})
T1	10.9 ^{d}	6.3 ^{e}	23.6 ^{b}	29.0 ^{c}	6.7 ^{d}	6.9 ^{a}	16.6 ^{d}	29.4 ^{c}	36.2^{d}	41.3^{c}	8.5^{d}	8.7^{cd}
T2	12.5 ^{c}	7.9 ^{d}	16.8 ^{a}	37.2 ^{b}	9.0 ^{c}	8.1 ^{c}	20.1 ^{c}	32.1 ^{b}	38.7^{c}	47.9^{b}	9.0^{c}	9.4^{bc}
T3	17.3 ^{b}	9.5 ^{c}	19.0 ^{c}	45.9 ^{a}	11.9 ^{b}	10.2 ^{b}	20.9 ^{c}	36.1 ^{a}	41.4^{b}	50.1^{ab}	9.6^{b}	9.5^{b}
T4	19.5 ^{a}	11.9 ^{b}	20.9 ^{c}	49.0 ^{ba}	13.8 ^{a}	12.0 ^{cb}	22.6 ^{cb}	38.9 ^{ab}	43.3^{b}	55.3^{a}	9.9^{a}	10.0^{a}
LSD (0.05)	1.98	-	2.75	-	0.42	-	-	-	-	-	-	-
CV (%)	5.4	-	6.2	-	4.8	-	-	-	-	-	-	-

C.P = Crude Protein; C.F = Crude Fiber; AC = Ash Content; ADF= Acid Detergent Fiber; NDF= Neutral Detergent Fiber; ME= Metabolizable Energy. Treatment means were separated with Duncan Multiple Range Test at 5% probability. Different letters on treatment means within each column show statistical differences at $P \leq 0.05$.

Conclusion: The present study clearly demonstrated that NPK fertilizer application significantly improves forage productivity and nutritional quality of rye grass and Rhodes grass under irrigated conditions. Increasing fertilizer levels resulted in substantial improvements in plant height, green fodder yield, and dry matter yield in both forage species. The highest plant height (104.8 cm in rye grass and 120.3 cm in Rhodes grass), green fodder yield (63 and 66 t ha^{-1}), and dry matter yield (17.8 and 21.2 t ha^{-1}) were recorded under T4, whereas the lowest values were observed in the control treatment. Nutritional quality also improved markedly with fertilizer application. Crude protein content increased from 10.9% to 19.5% in rye grass and from 6.3% to 11.9% in Rhodes grass, while ash content increased from 6.7% to 13.8% and 6.9% to 12.0%, respectively. Metabolizable energy improved from 8.5 to 9.9 MJ kg^{-1} DM in rye grass and from 8.7 to 10.0 MJ kg^{-1} DM in Rhodes grass. However, higher fertilizer levels also led to increased fiber fractions (ADF and NDF), which may reduce forage digestibility if not managed properly. Among the tested treatments, T3 (N 110 + P 70 + K 70 kg ha^{-1}) provided the most suitable balance between high forage yield and acceptable nutritional quality. Therefore, a moderately high fertilizer application is recommended for sustainable forage production in arid and semi-arid regions of Pakistan.

Recommendations: Based on the outcomes of the present study, the following recommendations are proposed:

- Application of a balanced NPK fertilizer at the T3 rate is recommended for sustainable forage production, as this level achieves an effective balance among forage yield, nutritional value, and digestibility.
- Rhodes grass is more suitable for systems where high biomass production is the primary objective, such as silage preparation and cut-and-carry feeding systems, whereas rye grass is better suited for situations where higher crude protein content in forage is desired.
- The use of excessive fertilizer rates should be discouraged unless accompanied by appropriate harvesting and management practices, as higher inputs may lead to increased fiber accumulation and a decline in forage quality.
- Future research should emphasize multi-harvest management systems, seasonal influences on forage performance, and economic assessments of fertilizer use to develop more precise and region-specific fertilizer recommendations for different agro-ecological zones of Pakistan.

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