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Evaluating the Effects of Nutrient Management on the Forage Yield, Quality and Soil Characteristics of Sugargraze: An Overview

Nandana S.K.[1], Sourabh Kumar[2], Kathi Hema Sri, P. Mansa Reddy, Neeraj Sharma, Rajeev, Shailja Sharma and Onkar R. Hirwe

Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara 144 411, Punjab, India

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ABSTRACT

Livestock rely heavily on fodder for nutrition, which is found in hay, silage, or fresh green plants.Forage crops are an essential component of a healthy and sustainable livestock farming system, providing essential nutrients, promoting good digestive health, and supporting the well-being of animals. Sugar grazeor sorghum-sudangrass hybrid is a type of forage crop that has become increasingly popular in livestock farming, is well known for its high productivity, Drought resistance, Silage production and versatility in a variety of soil conditions. It is widely grown in Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, Gujarat, and Madhya Pradesh. In addition to being a useful forage crop, it is also beneficial in grain production for human consumption, as a feedstock for biofuel, and as an industrial raw material. Even being a crucial crop for livestock, the information available on the utilization of both organic and inorganic nutrition sources in the cultivation of sugargraze is not sufficient till date to address the queries of farmers and motivate them for its cultivation.

Key words: *Livestock, Forage, Sugargraze, Organic, Inorganic*

Introduction

Due to the increased need for animal feed and growing knowledge of the nutritional advantages of forage crops, the global market for forage crops is expanding. Plants planted exclusively as animal feed are known as forage crops, and they are crucial to the production of cattle. The rising need for animal-based protein and the expanding global population are driving the demand for fodder crops. Additionally, the market for forage crops is expanding as a result of the employment of contemporary agricultural methods and cutting-edge technology like genetic engineering and precision farming. Alfalfa, clover, ryegrass, fescue, sugargraze, sorghum are some of the most important forage crops farmed worldwide. North America dominates the market, with Europe and Asia-Pacific coming in second and third. Meanwhile, according to a study that was seen in the Animal Sciences' Indian Journal, the amount of forage that India's livestock needs is estimated to be roughly 1.6 billion tonnes, but there is only 1.24 billion tonnes of it available, leaving 0.36 billion tonnes in short supply considering as a challenge (Singh *et al.,* 2013). This circumstance shows that in order to close the gap, the quantity of green forage must increase by 3.2%. (Kumar and Faruqui, 2010). The viability of dairy enterprises relies on the

([1] Research Scholar, [2]Assistant Professor)

presence of green forage for the livestock. Without an adequate supply of green forage, it becomes difficult to maintain the health of the cattle and ensure a consistent milk output, posing a challenge to the profitability of such businesses (Donald, 2006). Forage production along with utilization in India faces several major challenges in the Inadequate availability of good quality forage (Goyal *et al*., 2020). The availability of good quality forage in India is inadequate due to low investment in forage research and development, poor cultivation practices, lack of extension services, and limited access to inputs such as seeds, fertilizers, and irrigation. As a result, livestock production is hindered, and there is a dependence on crop residues and low-quality feeds. Another challenge is Low nutritive value of forage due to poor soil fertility, inadequate use of fertilizers, and improper harvesting practices (Kumar *et al.,* 2015). Limited knowledge and skills of farmers is also another challenge in the Forage Production and Utilization (Srinivasan *et al.,* 2013). This results in poor forage management practices, low yields, and reduced livestock productivity. Sugar graze being a protein rich and energy dense crop will be an excellent forage crop to address majority of the mentioned challenges. Sugar graze is a fantastic source of nutrition for animals because it has a high level of crude protein. It is the fourth most important fodder crop after maize, wheat, and rice (Dehinwal *et al.,* 2016). According to a research in the Journal of Dairy Science, on a dry matter basis, the crude protein content of sugargraze varied between 10.5% and 13.5% (DMB) (Kebede *et al*., 2008). Sugar graze is also high in energy and can provide an excellent source of digestible energy for livestock. According to a study published in the Journal of Animal Science, sugargraze had an average digestible energy content of 2.64 Mcal/kg DMB (Johnson *et al.,* 1995). Sugar graze is rich in essential minerals, including calcium, phosphorus, and potassium. According to a study published in the Journal of Animal Science, sugargraze had a calcium content ranging from 0.27% to 0.48% on a DMB basis, a phosphorus content ranging from 0.22% to 0.38% on a DMB basis, and a potassium content ranging from 1.50% to 2.60% on a DMB basis (Johnson *et al*., 1995). Sugargraze is rich in essential minerals, including calcium, phosphorus, and potassium. According to a study published in the Journal of Animal Science, sugargraze had a calcium content ranging from 0.27% to 0.48% on a DMB basis, a phosphorus content ranging from 0.22% to 0.38% on a DMB basis, and a potassium content ranging from 1.50% to 2.60% on a DMB basis (Johnson *et al*., 1995). A variety of soil types can support the growth of fodder crops. Avoid using acidic and saline soils; the pH of the soil should be between 5.5 and 7.0. In the summer, sugargraze should be irrigated every 7 days, and every 12 days during the rainy season. High moisture content in the crop is necessary for greater palatability. In forage crops, adequate watering will increase the healthy and anticipated biomass output. It's spring season sowing time is from Feb to April, Kharif from May to August, and Rabi (Central India and South India only) from September to November. Sugargraze can be trimmed around 45 to 50 days of age or at 70 to 90 days of age to get the ideal sugar content. Sugargraze can be trimmed for green fodder at 40 to 50 days of age, while 75 to 90 days of age is ideal for silage. And maximum height obtained by sugargraze will be in an average of 540 cm. During second cutting,, the crude protein content of Fodder can range from 5-7%,the crude fibre content from 23-25% and the Ash content ranges from 13-15%, Neutral Detergent fibre (NDF) ranging from 60-70%, Acid Detergent Fibre (ADF) content is ranges from 40-45% at 60 days after planting, Ether extract ranges from 1-2% at 80 days of planting. Maximum growth occurs at temperatures of 86 F and 100 F, whereas minimal growth takes place below 60 F and plant growth begins at 50 F soil temperature and the ideal pH of growth ranges from 5.5 to 7. Being the best sweet sorghum hybrid in the world with multiple cuts, its Brix value in juice varies from 16% to 18%, indicating high energy. Additionally, it has delicate internodes and supple stems for the maximum digestibility. It is also the ideal crop for making silage and hay because it has a strong resistance to drought, can grow up to 2.5 metres tall without lodging, and can produce the largest yield of up to 100 Mt per hectare. Because of its xerophytic properties, adaption capability, quick growing habit, strong ratoon ability, palatability, digestibility, and wide variety of possible uses as green fodder, dry roughage, hay, and silage, forage sorghum could be a strategic alternative among forage crops (Kumar and Chaplot, 2015).

The utilisation of both organic and inorganic nutrient sources is combined in the sustainable method known as integrated nutrient management (INM) to increase crop yield and soil fertility. In the case of forage crops like sugargraze, INM can result in

higher yields and better fodder quality, which can boost cattle health and its productivity (Das *et al*., 2016; Rajkhowa *et al*., 2015; Jat *et al*., 2017; Raja *et al*., 2019). The paper particularly analyses about the Nutrient Management effects on the forage yield and soil characteristics due to cultivation of sugargraze.

Effects of Nutrient Manangement on the Growth and Yield Attributes of Sugargraze

Integrated Nutrient Management (INM) is the process of increasing crop growth, productivity, and quality by mixing organic and inorganic fertilizers and other management strategies .Sugargraze is a versatile crop that can be used for biofuel, animal feed, and food items.Nitrogen is an essential nutrient for plant growth, yet it is also the scarcest in our soils. The application of nitrogen not only improves the levels of crude protein and metabolizable energy but also enhances the succulence and palatability of fodder crops. Chlorophyll and protein formation heavily rely on nitrogen. In a study conducted by Ram and Singh (2003) on forage sorghum, it was found that nitrogen application had a positive impact. It led to increased nitrogen uptake, crop growth rate, relative growth rate, as well as higher yields of forage and crude protein. Utilizing bio-fertilizers, such as Azospirillum and PSB, also plays a crucial role in enhancing nutrient availability, fertilizer use efficiency, and microbial biomass. These bio-fertilizers contain efficient strains of microorganisms capable of nitrogen fixation, phosphate solubilization, or cellulose decomposition.These preparations, whether applied to seeds, soil, or composting areas, serve to increase the population of microorganisms. This crucially enhances soil fertility through atmospheric nitrogen fixation, as stated by Mahdi *et al*. (2010). Kumar and Sharma (2002) reported that the supplementation of Azospirillum resulted in a 7.8% increase in green fodder yield and an 11.3% increase in dry fodder yield. Bhuriya *et al.* (2015) conducted a comparative study on various treatments and found that the application of 100-40 N-P kg ha-1 + Azospirillum significantly increased plant height at harvest, with a measurement of 162.33 cm. The heightened plant height observed in the Azospirillum treatment can be attributed to its positive impact on root growth, which, in turn, enhances nitrogen fixation in the soil, leading to robust crop growth. Previous studies by Sadhu *et al.* (1991), Tomar and Agrawal (1993), Karwasra and Dahiya (1997), Gadhethariya *et al*. (2000), Agrawal *et al.* (2005), Singh and Sumeriya (2005), Sheoran and Rana (2006), and Gupta *et al.* (2008) have also reported similar findings regarding the influence of Azospirillum on plant growth and nitrogen fixation. Bhuriya *et al.* (2015) further examined the effects of different treatments and found that the application of 100-40 (N-P kg ha-1) + Azospirillum resulted in the highest dry matter yield, reaching 134.7 q ha-1. The trend observed in dry matter yield aligned with that of green forage yield, indicating the impact of nitrogen application. Nitrogen plays a crucial role in protein synthesis and is also involved in the formation of chlorophyll, as well as carbohydrates and fatty acids. Several prior studies, including Gadhethriya *et al*. (2000), Kumar and Sharma (2002), Agarwal *et al.* (2005), Singh and Sumeriya (2005), Gupta *et al*. (2007), Gupta *et al.* (2008), and Mahdi *et al*. (2010), have consistently demonstrated that higher nitrogen rates result in increased dry matter yield. Crawford et al. (2018) conducted a study to investigate the impact of nitrogen levels and cutting management on multicut forage sorghum. Various parameters, such as plant height, number of tillers per meter row, leaf-to-stem ratio, green forage yield, and dry matter yield, were evaluated as nitrogen levels were raised up to 120 kg ha-1. The application of 120 kg N ha-1 exhibited significantly improved growth and yield characteristics compared to lower nitrogen levels of 60, 80, or 100 kg N ha-1. Specifically, the application of 120 kg N ha-1 resulted in the highest green forage and dry matter yields based on statistical analysis. These findings indicate that combining a nitrogen content of 120 kg N ha-1 with cut-

ting management involving the first cut at 60 days after sowing and two subsequent cuts at 50-day intervals is the most favorable approach for achieving higher sorghum yields under middle Gujarat conditions. Jat *et al.* (2013) and Singh *et al.* (2016) conducted studies demonstrating that the application of 2.0 t/ha of castor cake significantly increased the yields of green and dry fodder in sorghum. However, no significant differences were observed between the application of castor cake at 2.0 t/ha and farmyard manure (FYM) at 15.0 t/ha. Conversely, the lowest green forage output was observed with the application of castor cake at 1.0 t/ha. The study also revealed a 22.5% increase in green forage output compared to the previous year. Similar results were observed for dry fodder yield. The increased utilization of castor cake or FYM provides adequate and balanced nutrition to the plants throughout the growth cycle, resulting in improved plant growth and ultimately maximizing the green forage yield. The highest green forage yield was observed when applying the recommended dose of fertilizer (RDF) at 100%, as reported by Gopalan *et al.* (2007) and Singh *et al.* (2012). However, there was no statistically significant difference observed with the application of 75% RDF. The use of 100% RDF led to a 32.3% increase in green forage yield compared to the control, as well as increases of 22.6% and 11.7% compared to 50% RDF and 75% RDF, respectively. This increase in yield can be attributed to both enhanced growth stature and improved yield structure. Furthermore, the combination of optimal nutrient release and the effectiveness of bio-fertilizers in converting inaccessible plant nutrients into a usable form played a significant role in enhancing nutrient uptake and, consequently, promoting green forage production. Patil and Varade (2006) found that the application of a combination of recommended dose of fertilizer (RDF) and farmyard manure (FYM) resulted in the highest nitrogen and phosphorus uptake in sorghum. The application of castor cake, inorganic fertilizers, and bio-fertilizers might have contributed to higher dry fodder yield and improved availability of nitrogen and phosphorus throughout the crop growth period. According to the studies conducted by (Nanjappa *et al*., 2001; Vadivel *et al.,* 2001; Mahesh *et al*., 2010; Mukherjee, 2014; Kumar *et al.,* 2015). The utilization of increased levels of farmyard manure (FYM) showcased a significant positive influence on the growth and productivity of forage crops. Specifically, when compared to the application of 10 t FYM/ha, the application of 15 t FYM/ha resulted in notable enhancements in various plant characteristics. These included a significantly greater plant height (165.9 cm), increased number of leaves per plant (12.6), larger leaf area per plant (3624 cm^2), and longer internode length (12.1 cm) in the forage crop. These improvements can be attributed to the augmented nutrient provision facilitated by the higher FYM application, as well as the advantageous effects of decomposed organic matter on the physicochemical properties of the soil.

Effect of Nutrient Management on the Forage Qualities of Sugargraze

Suraj Kar *et al.* (2017) conducted a study to investigate the impact of various fertilizer sources on the quality of sugargraze, sorghum, and maize crops.. The findings revealed that sorghum had the highest dry matter (DM) content at 23.83%, while sugargraze exhibited the highest crude protein (CP) content at 10.42%, as well as elevated ether extract (EE) content at 1.66% and nutritional yields. Sugargraze also displayed the highest total DM output per hectare due to its substantial green fodder yield of 151.27 quintals per hectare. On the other hand, sorghum exhibited the highest ash content at 17.10% and neutral detergent fiber (NDF) content at 62.27%. Maize had the highest hemicellulose content at 25.15%. Irrespective of the crop under consideration, the application of 100% nitrogen through inorganic sources outperformed other types of fertilizers. The fodder's Protein Content was greatly affected by different quantities of organic manures and fertilizers, leading to notable changes. As nitrogen plays a vital role in protein composition, augmenting the nitrogen application rate using organic manures, inorganic fertilizers, and biofertilizers resulted in increased nitrogen availability, thereby boosting the protein content in the fodder. According to Yadav *et al.* (2013), the highest protein content in fodder sorghum was attained by applying the recommended dose of fertilizer (RDF) at 100%. In the case of maize crops, the greatest protein content was observed when farmyard manure (FYM) was applied at a rate of 12.0 tonnes per hectare (Kumar, 2015). Application of FYM at 15.0 tonnes per hectare resulted in a significant decrease in crude fibre content in the fodder, which was statistically comparable to applying 2.0 tonnes of castor cake per hectare. Among the various treatments, the lowest crude

fibre content was observed in the treatment combining 100% RDF with Azotobacter and PSB, which amounted to 29.28%. Conversely, the control treatment exhibited the highest crude fibre content.. The crude fibre content showed a considerable decline with increasing nitrogen levels. These findings indicate that increasing the nitrogen level from 50% to 100% RDF, along with the use of biofertilizers, improves the succulence and palatability of the fodder (Patel *et al*., 2018). In the agro-climatic conditions of North Gujarat, the application of either 2.0 tonnes per hectare of castor cake or 15.0 tonnes per hectare of farmyard manure (FYM), along with the recommended dose of fertilizer (RDF) at 100%, combined with Azotobacter and PSB, resulted in several positive outcomes for kharif fodder sorghum. These included increased green fodder yield, improved fodder quality, higher net returns, enhanced availability of soil nutrients (nitrogen and phosphorus), and increased nutrient uptake (Patel *et al*., 2018). For forage sorghum cultivated in sandy loam soil in middle Gujarat, India, the application of a 100-40 (nitrogen-phosphorus kg/ha) fertilizer ratio, in combination with Azospirillum, significantly enhanced various yield attributes. These included increased green forage yield, higher dry matter content, greater dry matter yield, elevated crude protein content, increased crude protein yield, and reduced neutral detergent fiber (NDF) content compared to other treatments (Bhuriya *et al.,* 2022).According to the studies conducted by Chandra and Ram (2007) and Pandey (2018), the treatment consisting of 75% NPK fertilizers along with farmyard manure (FYM) at a rate of 10 tonnes per hectare and zinc sulfate ($ZnSO_4$) at a rate of 25 kg per hectare resulted in the highest green foliage yield of the forage crop, reaching 580 quintals per hectare. This combination of nutrients and amendments may have contributed to the development of healthy roots in the plants, enabling them to absorb more moisture and nutrients from deeper soil layers. This improved root penetration and proliferation in the soil, leading to enhanced growth and higher green foliage yield. The application of a combination of poultry manure, biochar, press mud, and half of the recommended NPK treatment resulted in a significant increase in crude protein, brix %, acid detergent fiber (ADF), and acid detergent lignin content. This improvement in quality can be attributed to the enhanced availability of nutrients, soil organic matter (SOM), improved soil structure, and nutrient use efficiency (Faloye *et al.,* 2017; Calamai *et al.,* 2020). Organic manures are rich in nitrogen, phosphorus, and potassium (NPK), and their utilization in agricultural fields facilitates nitrogen uptake, resulting in a noteworthy augmentation of protein content in different plant components (Papini *et al.,* 2011; Adekiya *et al.,* 2020).

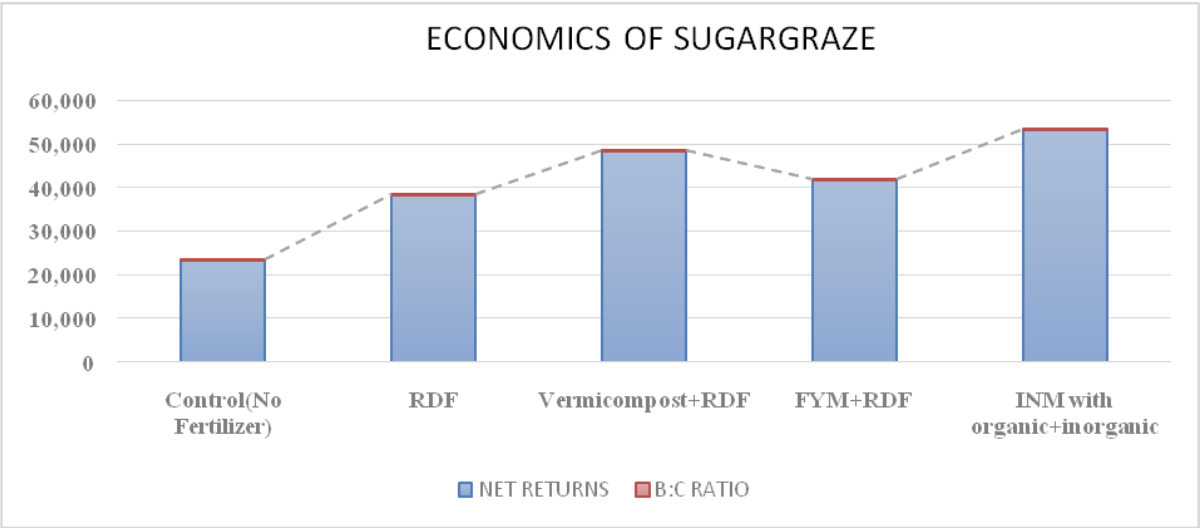
Effect of Nutrient Management on the Soil Properties of Sugargraze

In a study conducted by Dodiya *et al.* (2016), the effects of integrated nutrient management on soil parameters, such as pH, accessible nitrogen, organic carbon, phosphorus, alongwith potassium, were examined. The results indicated that implementing the integrated nutrient management approach led to notable enhancements in soil pH, organic carbon content, and the availability of phosphorus, potassium and Nitrogen. These improvements had a beneficial impact on forage productivity. Furthermore, Nandapure *et al*. (2011) demonstrated that the combined application of farmyard manure at a rate of 10 tonnes per hectare, along with inorganic fertilizers (100% NPK), positively influenced the overall performance of crops such as sorghum and wheat. This positive correlation was observed in relation to properties such as electrical conductivity, water stable aggregates, bulk density, available water capacity, coefficient of linear extensibility, and crop yield, as well as soil characteristics .According to the findings of Katkar *et al*. (2012), integrated nutrient management that combined farmyard manure (FYM) with 100% NPK yielded the highest value (2.45), followed by 150% NPK (2.15) and FYM (2.16). The control group had the lowest value (1.14) with 50% NPK of the recommended fertilizer dose (1.45), indicating an improvement in soil quality through integrated nutrient management. Dineshkumar *et al.* (2018) observed that organic fertilizers enhance the absorption of NPK and Mg even at lower application rates, leading to increased chlorophyll production. The increase in chlorophyll content, attributed to organic amendments, has also been associated with improved photosynthetic efficiency in plants, resulting in enhanced growth and biomass production (Dineshkumar *et al.,* 2018; Darini *et al*., 2017; Zameer *et al.,* 2021; Sutrisno *et al.,* 2018). According to Sutrino and Yusnawan, the application of organic manure enhances soil microbial population, soil organic matter (SOM), and structural stability, leading to improved growth and biomass production, as

observed by Asghari *et al.* (2018) and Hosseinzadeh *et al.* (2018 Combining organic and inorganic fertilizers provides a viable option for enhancing crop growth and biomass, surpassing the effectiveness of higher NPK fertilizer applications (Mubeen *et al.*, 2013). Hao *et al.* (2008) state that applying organic manures with lower NPK concentrations can promote microbial activity and nutrient availability, resulting in significant improvements in growth and biomass production characteristics. Organic amendments positively influence soil quality by enhancing nutrient release and availability to plants (Birkhofer *et al.*, 2008). The nutritional status of the soil is directly linked to grain yield and has implications for overall quality (Lima *et al.*, 2009). Furthermore, organic manure reduces soil bulk density by promoting soil biopores, aeration, SOM, and aggregate stability, which in turn improves soil water-holding capacity and porosity, leading to notable advancements in growth and biomass production (Gangwar *et al.*, 2006; Papini *et al.*, 2011)..

Effect of Nutrient Management on the Monetary Returns From Sugargraze

In the study conducted by Patel *et al.* (2018), it was discovered that the utilization of 100% recommended dose of fertilizer (RDF) with fertilizers resulted in significantly greater net returns and benefit-cost ratio (BCR) compared to the use of 75% RDF in combination with Azotobacter and PSB. The increased net returns can be attributed to notable enhancements in growth and yield characteristics, leading to higher green fodder production in this treatment. In their study, Kholu Mary *et al.* (2022) revealed that the application of 75% recommended dose of fertilizer (RDF) at a ratio of 60:40 NP kg/ha, combined with 2 tonnes of poultry manure per hectare (PM ha^{-1}), resulted in a very high net monetary returns of 60562 Rs/ha^{-1}, accompanied by a benefit-cost ratio (BCR) of 2.75. When compared to using only chicken manure or chemical fertilizers, the integrated nutrient management approach of utilizing 75% RDF with 2 t PM ha^{-1} proved to be the most effective strategy in terms of both fodder yield production and economic outcomes for forage crop cultivation. The adoption of integrated nutrient management treatments led to a significant improvement in the BCR of the forage crop. Sunita *et al.* (2022) found that the highest benefit-to-cost (B:C) ratio was achieved when 100% recommended dose of fertilizer (RDF) + PSB was utilized, surpassing other integrated nutrient management strategies. This could be attributed to the lower cultivation costs associated with 100% RDF + PSB and 100% RDF applications compared to other integrated nutrient combinations. Nawale *et al.* (2009) conducted a study where they compared different nutrient combinations applied to forage sorghum and assessed their impact on the succeeding chickpea crop. The findings revealed that the residual effect of 25% nitrogen (N) through farmyard manure (FYM) combined with 25% N through vermicompost and 50% N through recommended dose of fertilizer (RDF) applied to forage sorghum resulted in significantly higher values for nutrient uptake, gross returns, net returns, and the maximum benefit-to-cost ratio. In



Effect of nutrient management on economics of sugargraze cultivation

Table 1. Effect on economics of sugargraze by nutrient management (Modified from Patil *et al.,* 2018)

Crop	Treatments	Net Returns	B:C Ratio
Patel *et al.,* 2018	Control (No Fertilizer)	23,500	1.2
Patel *et al.,* 2018	RDF	38,500	1.9
Patel *et al.,* 2018	Vermicompost + RDF	48,500	2.4
Patel *et al.,* 2018	FYM +RDF	42,000	2.1
Suryawanshi *et al.,* 2020	Integrated nutrient management with organic and inorganic fertilizer	53,500	2.7

contrast, applying reduced or higher values of RDF in combination with organic manures or solely using inorganic fertilizer in the preceding forage sorghum crop yielded inferior outcomes. According to Lingaraju *et al.* (2023) applying a combination of 7.5 tonnes per hectare (t/ha) of farmyard manure (FYM) and 100 percent recommended dose of fertilizer (RDF) (100:50:25 N, P_2O_5, and K_2O kg/ha) resulted in significantly higher gross returns (Rs. 69,059/ha) and net returns (Rs. 51,659/ha). These returns were comparable to the use of vermicompost at a rate of 2.5 t/ha along with 100 percent RDF, which yielded gross returns of Rs. 66,513. Alternatively, combining poultry manure at 1.0 t/ha with 100 percent RDF resulted in a significantly higher benefit-to-cost ratio. In a separate study conducted by Vikram Shiyal *et al*. (2020), the treatment consisting of 5 t/ha of FYM, 25 percent nitrogen (N) from FYM, 75 percent RDF, and bio-fertilizer recorded the highest net returns (Rs. 2,35,153/ha) and a benefit-to-cost ratio of 6.87. Comparatively, the application of 100 percent RDF or 5 t/ha FYM with 25 percent N from FYM and 75 percent RDF with bio-fertilizer yielded a benefit-to-cost ratio of 6.66.

Conclusion

Based on the data gathered, it is possible to conclude that effective nutrient management is critical for obtaining optimal development, yield, quality, and economic benefits from sugargraze cropping systems.Vermicompost, nano-urea, and farmyard manure (FYM), along with various other organic and inorganic fertilizers, have the potential to enhance soil fertility and improve crop productivity.. Furthermore, adequate nitrogen and phosphorus fertilizer rates can greatly increase crop production and profitability, while potassium can improve the quality of harvested biomass.. Excess fertilizer application, on the other hand, might have a negative impact on soil characteristics and crop performance overall. To maximize the benefits of sugargraze production, it is critical to utilize fertilizers in a balanced and sustainable manner, taking into account soil fertility status, crop requirements, and economic considerations.

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