**Original Research Article**

**Participatory evaluation and selection of improved forage production technologies for underground irrigation in Korra, Denan district, Shebelle Zone, Somali Region, Ethiopia**

**Abstract**

**Background:**In arid and semi-arid regions like Denan district, access to quality forage is a major constraint to sustainable livestock production. Enhancing forage availability through improved technologies is essential, particularly under irrigation-fed systems where water can be utilized efficiently. This study was conducted to address the forage gap by introducing and evaluating improved forage varieties suited to local conditions.

**Objectives:**The main objective of the study was to introduce and evaluate the performance of improved forage technologies-specifically Sudan grass, Napier grass, and Buffle grass-through participatory on-farm trials under irrigation-fed cultivation in Denan district during the 2022 production season.

**Methods:**The experiment employed a Randomized Complete Block Design (RCBD) with three replications. Three forage varieties (Sudan grass, Napier grass, and Buffle grass) were tested under irrigation conditions. Data were collected on agronomic traits including flowering days, maturity days, plant height, and biomass yield. Statistical analysis was conducted using SAS software to assess significant differences among the varieties.

**Results:**The analysis revealed significant differences (P<0.05) among the forage varieties in terms of growth and yield parameters. Sudan grass attained the highest plant height (185.3 cm), followed by Napier grass (161.7 cm), while Buffle grass recorded the shortest height (93 cm). Sudan and Buffle grasses matured significantly earlier (P<0.05) than Napier grass. In terms of biomass yield, Sudan grass outperformed the others significantly (P<0.01). Napier grass, however, recorded a significantly higher dry matter yield (P<0.05) than Buffle grass. Participating pastoralists ranked Sudan grass highest based on forage yield, palatability, early maturity, drought tolerance, ease of establishment, and manageable harvesting height.

**Conclusion:**Sudan grass demonstrated superior performance in growth, yield, and farmer-preferred traits, making it a suitable forage option for irrigation-based cultivation in Denan Woreda. It is therefore recommended for adoption by farmers in Denan and similar agro-ecological zones. Further multi-location and multi-season trials are advised to confirm its broader adaptability and performance consistency.

***Keywords*:**Improved Forage Varieties, Biomass Yield, Sudan Grass, participatory, On-Farm Trials

1. **Introduction**

The global livestock sector is undergoing rapid growth, primarily driven by population increases, rising incomes, and urbanization. According to the World Health Organization (2013), annual meat production is projected to increase from 218 million tons in 1997–1999 to 376 million tons by 2030. In developing countries, this expansion is fueled by changing dietary habits, growing populations, and improved income levels (FAO, 2003). Ethiopia, as one of the leading livestock-producing nations in Africa, boasts approximately 60.39 million cattle, 31.30 million sheep, 32.74 million goats, 2.01 million horses, 8.85 million donkeys, 0.46 million mules, 1.42 million camels, and 56.06 million poultry (CSA, 2018). The livestock sector contributes about 16–25% to the national Gross Domestic Product (GDP) and 40–44% to the Agricultural GDP (Stapleton, 2016). However, despite this large livestock population, productivity remains low due to multiple constraints, with inadequate feed supply and poor nutritional quality being the most pressing challenges (Tolera et al., 2012).

In Ethiopia, about 56.23% of livestock feed originates from grazing, 30.06% from crop residues, and only 1.21% from agro-industrial by-products (CSA, 2015). To address these feed-related challenges, strategies have been proposed that focus on developing and disseminating improved forage technologies tailored to local resources, farmers’ needs, and livestock production goals. These efforts aim to mitigate animal feed shortages while promoting environmental sustainability. However, implementation has been inconsistent across the country due to resource limitations, vast land coverage, and insufficient institutional attention.

Cultivated forages and pastures represent a promising solution to address feed scarcity and support higher livestock productivity. However, their adoption remains low due to limited extension services, inadequate farmer training, and restricted access to forage seeds and planting materials (GRM, 2007). One viable approach is the utilization of indigenous, cultivated, multipurpose forages, which are often well-adapted to local agro-ecologies, familiar to smallholder farmers, and require minimal inputs (Abebe et al., 2008; Anele et al., 2009). Under current Ethiopian conditions, these indigenous forages offer a practical and sustainable option to improve animal feed supply (Shapiro et al., 2015).

Agriculture remains the backbone of Ethiopia’s economy, supporting over 80% of the population, contributing about 45% of GDP, and accounting for more than 90% of export earnings (MOA, 2010). Livestock alone contributes 30–35% of agricultural GDP and over 85% of smallholder farmers’ cash income (Befekadu and Berhanu, 2000). Beyond its economic value, livestock plays multiple roles in Ethiopian households- providing food, draft power, manure, and serving as a source of income, investment, and social status (Ehui et al., 1998; Belete et al., 2010).Nevertheless, the full potential of Ethiopia’s livestock sector is constrained by feed shortages, low genetic potential, poor animal health services, and suboptimal management practices (Zegeye, 2003). In both highland and lowland areas, the quality and quantity of natural pastures are declining due to overgrazing, land degradation, and climate change, further exacerbated by population pressure and crop encroachment (Nandi and Haque, 1988).

These dynamics are creating a widening gap between feed demand and supply, driven by the growing livestock population (Lulseged, 1995).This increasing demand for livestock products, especially in urban areas, underscores the urgent need for sustainable feed technologies and improved management practices (Nandi and Haque, 1986). However, reliable statistical data on feed availability and distribution are limited. The adoption of improved forage technologies remains low due to a lack of awareness, limited technical support, and insufficient seed systems (Othill, 1986). These constraints are particularly severe in drought-prone and arid areas with short rainy seasons.

Despite efforts by research institutions and universities over the past few decades to develop and promote cultivated forage crops, the number of varieties and production packages suitable for Ethiopia’s diverse agro-ecological zones and farming systems remains inadequate. Addressing this gap through participatory forage evaluation, especially under irrigated conditions in vulnerable regions, is crucial for improving livestock productivity and household resilience.Therefore, given the critical role of technological options and the impact of climate change, there is a pressing need for action-oriented research that focuses on the introduction of different varieties of improved forages.

1. **Materials and Methods**
   1. **Description of the Study Area**

The study was conducted in the Shebelle Administrative Zone of the Somali Regional State, specifically in Denan District, particularly in Korra. This district is located along the main road between Godey and Korahay (Qabridahare) at coordinates 6°30′N, 43°30′E. The area experiences temperatures ranging from 22°C to 34°C and receives an average annual rainfall of 275 to 300 mm. There are two main rainy seasons: The Gu’ from April to June and the Deyr from October to December (Save UK, 2015). According to projections from the Central Statistical Agency in 2018, Denan has an estimated total population of 87,380, comprising 49,703 men and 37,677 women.

* 1. **Sample size Selection and Establishment of PAPREGs**

Before the establishment of the PAPREGs, discussions were held with community elders, clan leaders, and relevant officials regarding the purpose of the project and its interventions. Based on these discussions, 25 members were identified and formed the research group. During the selection of PAPREG members, we considered the needs, potential, gender, and age of the pastoralists, ensuring that interventions were appropriate for their land. Throughout the project activities during the intervention period, all PAPREG members actively participated.The trial site was selected based on accessibility, its proximity to Oman Stream, and the consensus of all PAPREG members.

* 1. **Participatory Farm Evaluation of Improved Forage**

Three drought-resistant improved forage species, Sudan Grass, Buffle Grass, and Napier Grass, were used in the farm trial. The trial was conducted on the land of twenty-five selected PAPREG members. Before the commencement of the trial, short-term training was provided to all PAPREG members to explain the project's objectives.

* 1. **Experimental Design and Treatments**
     1. **Plantation**

Seedbed preparation was completed prior to planting the forage crops. Seeds of Sudan Grass, Napier Grass, and Buffle Grass were sown across the entire plots of the twenty-five selected PAPREG members (10m x 10m for each crop) in a randomized complete block design with three replications, covering a total area of 1 hectare.All plots received the recommended seed rates of 10 kg/ha for Sudan Grass, 1 kg/ha for Napier Grass, and 2,000–2,500 cuttings/ha for Buffle Grass. The recommended fertilizer application rate for all plots was 18/46 N/P₂O₅ kg/ha, which was applied at planting.

* 1. **Data Collection**

Seed viability was determined by germinating scarified seeds on moist filter paper in Petri dishes. All plants from the plots were harvested at a height of 5 cm above ground level. Data on plant height (PH) was collected by randomly selecting ten plants from each experimental plot and measuring them with a meter stick from ground level to the tip. Yield was expressed as quintals of dry matter per plot. The dry matter content of the plants was measured after oven-drying at 60°C for 24 hours. Additionally, the PAPREG members compared and evaluated the performance of each improved forage crop.

* 1. **Data Analysis**

The data on yield and yield components collected from the forages were summarized and analysed using analysis of variance (ANOVA) in SAS statistical software. Treatment effects were assessed by Analysis of Variance (ANOVA) using SAS ver.26 computer packages (Gomez and Gomez, 1984). Treatment means were separated using Least Significant Difference (LSD) in SAS ver.26. Differences among treatment means were separated using Duncan’s Multiple Range Test (DMRT) when treatment effects were significant (P < 0.05). Data collected from PAPREGs' ranking of each treatment was summarized and analysed using pairwise ranking.

1. **Results and Discussion**

The current findings on Sudan Grass, Napier Grass, and Buffle Grass align with and expand upon previous research on biomass production, plant height, and maturity days for these forage species under various agro-ecological conditions.

* 1. **Biomass Production**

Studies by SoRPARI (Year) reported higher biomass yields for Sudan Grass (18.6 qt/ha), Napier Grass (13.9 qt/ha), and Buffle Grass (9 qt/ha). The results indicated significant differences (P < 0.05) in biomass yield (qt/ha) among these species. The superior biomass yield of Sudan Grass observed in this study confirms its reputation for high productivity and adaptability, as documented by Abebe et al. (2017), who noted Sudan Grass’s ability to produce substantial dry matter in saline and marginal soils. Similarly, other research (Mulugeta et al., 2019) emphasizes Sudan Grass's genetic potential for biomass accumulation, especially in sub-optimal soils.

* 1. **Plant Height and Maturity Days**

The recorded plant heights (185.3 cm for Sudan Grass, 161.7 cm for Napier Grass, and 93 cm for Panicum maximum) are consistent with previous findings by Tesfaye et al. (2018), who observed that Sudan Grass generally exhibits taller stature compared to other forages, owing to its vigorous growth habit and genetic traits. The earlier maturity of Sudan Grass and Buffle Grass compared to Napier Grass aligns with the phonological patterns reported by Muthoni et al. (2020), who found that Sudan Grass typically matures earlier, which can be advantageous for forage harvesting in regions with limited growing seasons.

The results indicated significant differences (P < 0.05) in maturity days and plant height among this species

The variations in yield and growth parameters are often linked to environmental conditions.The superior performance of Sudan Grass in this study can be attributed to its genetic adaptability to saline, poorly fertile soils and water-stressed environments, as highlighted by Gebeyehu and Tsegaye (2016). Conversely, lower yields across all species in this research compared to previous reports by SoRPARI may result from soil salinity, inadequate irrigation, and sub-optimal management practices, consistent with findings by Desta et al. (2015), who emphasized the influence of agro-ecological stressors on forage productivity.The results reinforce the importance of selecting forage species suited to specific agro-ecological conditions. Sudan Grass’s robust performance underscores its potential as a resilient and high-yielding forage in saline and degraded soils. However, optimizing management practices, such as irrigation, fertilization, and soil amelioration crucial to maximize yields, as suggested by earlier studies (Yilma et al., 2019).

Table 1. Biomass Yield, Height, and Tillers of Three Grasses under Irrigation in Dhenan

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| --- | --- | --- | --- | --- | --- |
| **Tested Species** | **Flowering days** | **Maturity (days)** | **Plant height (cm)** | **Biomass (qt/ha)** |  |
| **Sudan Grass** | 47.3± a | 67± a | 185.3± a | 18.6±a |  |
| **Napier Grass** | 54.3±12b | 84.7±0.8a | 161.7±10b | 13.9±18b |  |
| **Buffle Grass** | 64±2.9b | 74± 0.3b | 93±4.5b | 9±1.58c |  |
| **P-value** | 0.0025 | 0.0026 | 0.0035 | 0.0080 |  |

SEM = Standard error of mean;biomass (qt/ha); biomass yield quintal per hectare

**Figure 1. Biomass Yield, Height, Maturity, and Flowering of Sudan, Napier, and Buffle Grasses**

* 1. **Farmer’s perception towards the experimental grasses**

Understanding farmers’ perceptions and preferences is essential for the successful adoption and scaling of forage technologies. Numerous studies emphasize that farmers evaluate forage species based on key attributes such as biomass yield, palatability, maturity period, drought tolerance, ease of establishment, and overall management requirements. Incorporating these preferences into forage development efforts enhances the likelihood of sustained use and impact at the community level.

* 1. **Farmer Preferences and Selection Criteria**

In various agro-ecological contexts, farmers tend to prioritize forage species that offer high biomass yield, early maturity, drought resistance, and ease of management. For instance, Ayele et al. (2018) found that pastoralists in Ethiopia favored Sudan Grass due to its high forage yield, early maturity, and drought tolerance, which aligns with the findings of the current study. Similarly, Mekuria and Worku (2019) reported that farmers preferred Napier Grass for its good palatability and ease of establishment, although they recognized its relatively later maturity compared to Sudan Grass.

* 1. **Farmer Participation in Selection and Adoption**

Participatory approaches involving farmers in selecting forage species have been shown to enhance adoption rates. According to Gebremedhin et al. (2017), when farmers are actively involved in evaluating forage options based on their local knowledge and experience, the selected species are more likely to be adopted and managed effectively. The current study’s participatory approach, where all pastoralist members participated in ranking the forage species, is consistent with this literature, emphasizing the importance of farmer involvement in decision-making processes.

* 1. **Perception of Forage Attributes**

Research by Teshome et al. (2016) demonstrated that pastoralists’ preferences are heavily influenced by attributes such as early maturity, drought tolerance, and ease of management, which are critical in semi-arid and drought-prone regions. The current study’s finding that Sudan Grass was ranked first based on these criteria confirms the trend observed in other studies, indicating that farmers value forage species that can withstand environmental stresses while providing reliable feed.

* 1. **Implications for Forage Development**

The alignment between farmer preferences and scientific assessments of forage performance underscores the importance of participatory breeding and selection strategies. As noted by Tesfaye and Abebe (2019), integrating farmer perceptions with scientific data enhances the relevance and acceptability of forage options, leading to better utilization and sustainability.

**Figure 2: Pastoralists’ ranking of grass species based on yield, palatability, and drought tolerance**

* 1. **Pair-wise Ranking Matrix for Selection Criteria**

A pair-wise ranking of the pastoralists’ selection criteria was conducted to identify and prioritize the most important traits for future forage improvement in the community. The pastoralists voluntarily compared the criteria and ranked them in order of importance. Accordingly, drought tolerance was ranked first among all criteria, while palatability was also highly prioritized. This finding is supported by Mganga et al. (2015) and Aberra et al. (2010). Regeneration capacity and biomass yield were ranked third and fourth, respectively, followed by early maturity. These results are comparable to the findings of Belete et al. (2018).

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1. **Conclusion**

The study findings indicate that Sudan grass is well adapted to the environmental conditions of the study area, demonstrating superior performance in terms of plant height, biomass yield, and dry matter production. Among the grass species evaluated, Sudan grass consistently outperformed Napier and Buffle grasses, both agronomically and in terms of pastoralist preference. Its favourable characteristics, such as drought tolerance, early maturity, and high biomass yield, make it a valuable forage resource in regions facing declining pasture quality and quantity. These results highlight Sudan grass’s potential to enhance livestock feed availability in arid and semi-arid areas, where traditional roughage sources are often insufficient in quality and energy content.

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