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Fodder Grasses and Irrigation Strategies: A Pathway to Fodder Sustainability in India

Greeshma. U [a++*], Usha C Thomas [b#], Shalini Pillai, P [a†], G. Gayathri [c‡] and Safeer, M. M. [b^]

[a] *Department of Agronomy, College of Agriculture, Vellayani, India.*
[b] *Instructional Farm, College of Agriculture, Vellayani, India.*
[c] *AICRP on Forage Crops & Utilization, COA, Vellayani, India.*

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Indian agriculture heavily depends on the livestock sector, which significantly influences the financial system. Fodder, derived from crop residues, cultivated feed, and grazing lands, is a cost-effective nutrient source essential for sustaining the dairy industry. However, India faces severe fodder shortages—63.5% for green fodder and 23.5% for dry residues—exacerbated by rising livestock populations and declining fodder cultivation areas. Low livestock productivity, driven by

[++]PhD Scholar;
[#]Professor (Agronomy) & Head;
[†]Professor & Head;
[‡]Assistant Professor (PB&G);
[^]Assistant Professor (Pathology);
**Corresponding author: E-mail: greeshmaudayan96@gmail.com;*

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inadequate feeding and healthcare, compounds the challenge. To meet growing fodder demands, many Indian dairy farmers have turned to cultivating perennial grasses, such as hybrid Napier grass, which provides year-round fodder. Strategic irrigation practices can play a vital role in mitigating water use, improving water-use efficiency, and reducing costs. This article examines the current challenges in fodder production, emphasizing the importance of optimizing irrigation practices to enhance water use efficiency. It explores various irrigation methods, including drip and sprinkler systems, and discusses their impact on fodder crop productivity. The need for high-quality fodder seeds, improved management practices, and innovative irrigation scheduling techniques is highlighted as essential for bridging the gap between fodder demand and supply. Addressing these challenges is vital for improving livestock productivity, supporting small and marginal farmers, and ensuring food security in India.

Keywords: Fodder production; irrigation; irrigation scheduling; livestock productivity.

1. INTRODUCTION

India is mainly an agricultural country, with two-thirds of its rural population relying on livestock for their livelihoods. The livestock sector contributes 25.6% to the total agricultural GDP and accounts for 4.1% of the nation's overall GDP (GOI, 2021).

In order to ensure food security, livestock rearing is crucial, particularly for small and marginal farmers. However, the productivity of these livestock is 20-60 per cent lower than the global average due to improper feeding and lack of health care. Being the first in buffalo and cattle population, the present fodder production of our country is not able to meet the fodder demand. Currently, the country is facing a shortage of 63.5 and 23.5 per cent in green and dry crop residues, respectively. If the current scenario continues, the deficit will increase to 65.45 per cent in 2030 (IGFRI, 2013).

Dairy farmers in India are increasingly turning to cultivating perennial grasses in fodder rotations to ensure a consistent supply of green and dry fodder for their animals throughout the year (Singh et al., 2002). Therefore, it is crucial to increase the productivity of existing cultivated fodder crops to satisfy the rising demand for cattle feed.

One of the major challenges in the cultivation of fodder crops is its huge requirement of water for irrigation. Optimizing the timing of irrigation for fodder crops can enhance their water efficiency, contributing to greater conservation of water resources. So, overcoming these difficulties in fodder cultivation may attract a greater number of farmers to invest in fodder cultivation, and the present deficit in feed for livestock can be overcome.

1.1 Current Situation of Fodder Production in India

Fodder production in India shows significant regional variation, with its utilization influenced by cropping pattern, climate, socioeconomic conditions, and the type of livestock. Cattle and buffaloes are usually fed fodder from cultivated regions, with collected grasses and top feeds providing minor supplements (Shashikala et al., 2017). Fodder crops are cultivated or harvested to feed animals in various forms, such as forage (freshly cut and fed green), silage (preserved in anaerobic conditions), and hay (dried or dehydrated green).

Farmers in many regions are cultivating grasses and legumes like hybrid Napier grass, Guinea grass, paragrass, velvet bean, and stylo. The land area used for permanent pastures and other grazing land is 10.34 M ha (GOI, 2021) and has been gradually declining over time. Fodder availability stands at 400.6 mt, while the requirement is 1097 mt, resulting in a deficit of approximately 63.5 percent (Roy et al., 2019).

Crop residues are anticipated to supply 54 per cent of total fodder supply, whereas rangelands contribute 18 per cent, and only 28 percent coming from cultivated fodder crops (Hegde, 2010). According to Pathak and Dagar (2015), pasture productivity has been declining as a result of overgrazing. There is currently a net deficiency of 35.6 per cent green fodder, 10.95 per cent dry fodder and 44 per cent concentrate feed materials in the country (IGFRI Vision 2050, 2015). By 2050, the demand for green and dry feed will be 1012 and 631 million tonnes, respectively (Fig. 1).

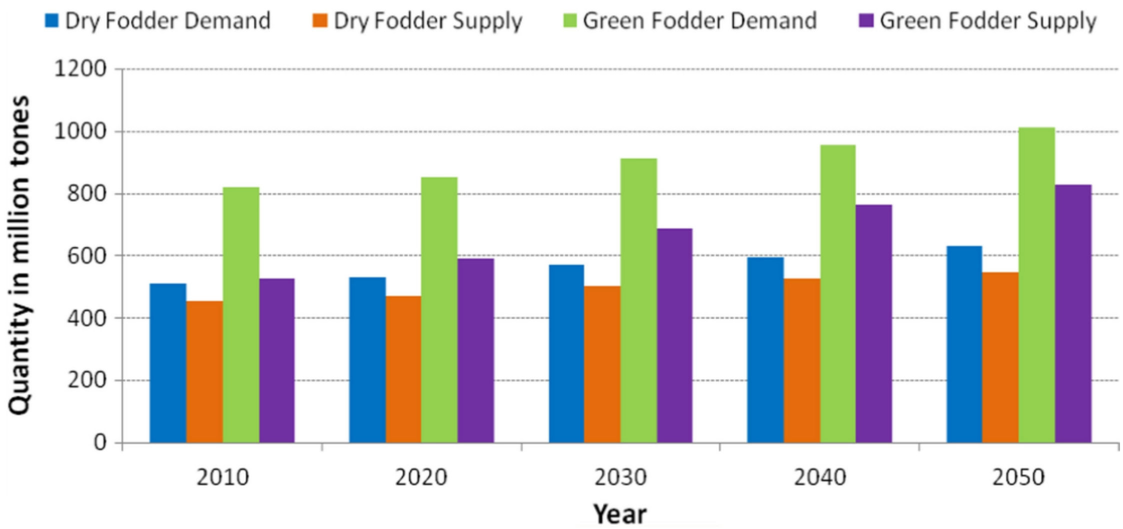

Fig. 1. Year-wise Demand and supply of green and dry fodder in India
(Source: IGFRI, 2015)

Green forage production must increase by 1.69 percent annually to address the deficit, yet cultivated fodder occupies only 4 percent of the total agricultural land (8.4 million hectares) in the country, a figure that has remained unchanged for decades (Meena et al., 2018).

In Kerala, although there has been a slight increase in the cultivated fodder area from 4,890 hectares in 2015 to 5,650 hectares in 2019, it remains limited. Fodder availability in Kerala is 94.5 million tons, while the requirement is 232 million tons, leaving a deficit of approximately 60 percent (FIB, 2019).

1.2 Significance of Green Fodder

Green fodder is a cost-effective nutrient source for dairy animals, known for its high palatability and digestibility. Micro-organisms present in green fodder aid in enhancing the digestibility of crop residues in a mixed feeding system. It also promotes good health and boosts breeding efficiency in animals. Increasing the amount of green fodder in their diet can help reduce milk production costs.

Krausmann et al. (2008) noted that livestock consumed almost two-thirds of global biomass obtained from grazing lands and croplands. In addition to permanent grazing pastures, forages include herbaceous and woody plants, as well as both perennial and short-lived forage crops used in cut-and-carry systems. Forage-based systems encompass all systems that incorporate forage plants, such as ley systems, which rotate between cropping and pasture, along with agro-pastoral systems, and rangelands.

Fodder crops offer several advantages that make them well-suited for adapting to climate change. They can withstand moisture stress and dry conditions, and are tolerant of various soil issues such as alkalinity, acidity, and waterlogging. Fodder crops are generally adaptable to low soil fertility and have a lower incidence of pests and diseases, allowing them to endure harsh environments. They also possess beneficial traits like soil and water conservation.

Dairy farmers in India are increasingly turning to perennial grasses in fodder-based rotations to meet the year-round demand for green and dry fodder for their livestock (Singh et al., 2002). Among these grasses, the Bajra Napier (BN) hybrid, an interspecific cross between bajra and napier grass (*Pennisetum glaucum* x *Pennisetum purpureum*), stands out as the most popular. This is due to its adaptability to diverse climates, low cultivation costs, resistance to pests and diseases, resilience to grazing by wild animals, ease of propagation through vegetative materials, and excellent response to fertilizer application (Singh et al., 2018).

1.3 Challenges in fodder cultivation

India is currently facing significant pressure due to the large-scale exploitation of forest resources for fuelwood, timber, and fodder, along with poor forest management and frequent wildfires. There is a severe shortage of fodder, particularly green and nutritious types, which is a major factor behind the low productivity of livestock, especially in hilly regions. The primary reasons for this low productivity include inadequate availability of high-quality fodder, feed, and limited grazing opportunities. The main constraints can be described as;

1. **Rapidly expanding livestock population:** As per the 20th Livestock Census conducted in 2019, India's total livestock population stands at 535.82 million, marking a 4.6 per cent increase compared to the previous Census in 2012, with an annual growth rate of 0.66 per cent (GOI, 2021). However, the large livestock population and limited availability of fodder have created a substantial gap between the demand and supply of forage crops. A considerable portion of fodder resources is wasted on maintaining an excessive number of undernourished and low-yielding animals, which has contributed to the degradation of pastures.
2. **Reduced area under fodder cultivation:** The fragmentation of families has led to the division of land, resulting in very small landholdings. Farmers tend to have biased preferences when selecting crops. Consequently, the agricultural land ratio does not allow for land conversion from food production to fodder cultivation. As a result, the area dedicated to fodder crops remains limited.
3. **Uncontrolled grazing of dairy animals:** Unregulated grazing has resulted in a reduction of biomass availability and created numerous issues in the pastures. Overgrazing and constant pressure have significantly harmed the fodder cultivated lands.
4. **Poor management practices:** Management practices are crucial in influencing grassland productivity. Factors such as the presence of low-quality and unproductive grass species, insufficient fertilizer application, lack of legumes, improper cutting techniques, and unregulated grazing significantly contribute to low grassland productivity.
5. **Shortage of High-Quality Fodder Seeds:** The absence of quality seeds, particularly high-yielding varieties and hybrids, results in low productivity of forage crops. The availability of good-quality seeds or planting material is a significant constraint affecting both the area cultivated and the overall production of forage crops (Parihar, 2010). Major factors hindering the availability of quality fodder crop seeds include indeterminate growth, uneven maturity, seed shattering, climatic conditions, and insufficient seed production technology, along with inadequate management practices and the lack of a dedicated forage seed market (Vijay et al., 2013).
6. **High demand of water for irrigation:** The primary constraint on the global expansion of fodder cultivation is the lack of water. The demand for water is rising due to rapid population growth, improved living standards, advancements in industry and municipal services, and the effects of global warming. Various irrigation scheduling methods and micro irrigation offer a practical and efficient way to deliver water directly to the soil and close to the plants, minimizing water loss, and enhancing water productivity. Implementing such irrigation methods for fodder crops can improve water use efficiency and promote water conservation, potentially encouraging more farmers to invest in fodder cultivation, as water scarcity is a significant barrier to fodder cultivation.

1.4 Water Requirement of Fodder Crops

This grass exhibits high resilience and typically doesn't need irrigation in the monsoon season if rainfall is adequate and evenly spread. However, it's crucial to ensure good drainage in the field during the rainy season, as the crop is susceptible to waterlogging. The frequency of watering varies based on rainfall levels and weather conditions.

Due to its perennial nature of fodder crops, it requires continuous irrigation for better productivity. But, the excessive application of huge quantity of water with long intervals leads to water logging (Marathe et al., 2001) mainly in surface method of irrigation. The feeder roots of fodder crops are mainly concentrated in the top layers. The application of water on the surface layers will lead to imbalanced nutrient distribution in the soil, which may negatively impact plant development. (Marathe et al*.,* 2016).

Application of water in small doses often help them for maximum usage efficiency and increased crop yields. This also minimizes percolation and evaporation losses, enhancing water use efficiency through the maintenance of optimal soil moisture levels near the root zone (Vennila and Ananthi, 2019).

1.5 Different Methods of Irrigation in Fodder Crops

Water for irrigation can be delivered through sprinkler, surface, or drip irrigation systems, each with its own benefits and drawbacks. These systems distribute water either through gravity flow, like in surface irrigation, or through pressurized flow, as in sprinkler and drip irrigation.

Utilizing micro-irrigation techniques for fodder crops can enhance water use efficiency, leading to increased water conservation. This improvement may incentivize more farmers to invest in fodder cultivation, as water is often cited as a significant obstacle for fodder crop cultivation. (Varshini and Jayanti, 2020). Vennila and Ananthi (2019) found that irrigation through drip at 100 per cent potential evapotranspiration (PE) maintained the availability of moisture throughout the crop season.

a) **Sprinkler Systems*:*** When sprinkler systems are appropriately planned and supervised to ensure that the water application aligns with the soil's capacity, thereby issues like runoff and waterlogging can be prevented. However, a drawback of all sprinkler systems is the risk of foliar damage in certain crops, particularly if the water contains high salt concentrations.

A study was conducted by Taha and Ghandour (2021) to analyse the impact of four different irrigations (125, 100, 75% ETo, and farmer practice) on the yield of fodder pearl millet and reported that in comparison to the normal farmer irrigation method, the amount of water saved was 22, 38, and 53 per cent for the 125, 100, and 75 per cent ETo treatments respectively.

b) **Surface irrigation*:*** Surface irrigation systems are suitable for deep soils ranging from clay to loam texture. Enhancing the efficiency of surface irrigation can be achieved by employing gated pipe or concrete delivery channels, which also help to reduce weed issues along field borders. Adequate water storage capacity in the soil is necessary due to the longer intervals between irrigations. The two most prevalent surface irrigation systems are flood irrigation with furrows and flood irrigation with basins.

c) **Drip irrigation:** Drip irrigation ensures the total eradication of water stress, even during severe water scarcity. In comparison to traditional irrigation methods, the pipe network and emitters utilized in drip irrigation systems deliver water close to the crop's root zone, reducing water loss and leading to enhanced water use efficiency (Singh et al., 2013). Positive outcomes have been noted in pastures, hay, and forage crops, particularly when lines are spaced 30 inches apart in sandy soils and 40 to 80 inches apart in medium-textured soils. Micro irrigation has enabled the maintenance of available soil moisture at low water tension almost consistently throughout the entire growth period, leading to substantial water savings of up to 50 percent (Patel et al., 2006). Drip irrigation is a precision technique that aims to apply irrigation water accurately, in the right location, amount, and timing (Almarshadi and Ismail, 2011).

Application of nutrients through drip irrigation has positively influenced the crop growth parameters such as plant height, tiller count, and leaf number, which will further leading to increased biomass yield per plant and per hectare. This is attributed to the uniform distribution of nutrients within the crop's root zone through fertigation, thereby minimizing nutrient loss caused by volatilization and leaching. (Vennila and Sankaran, 2017).

Vennila and Ananthi (2019) found that irrigation through drip at 100 per cent potential evapotranspiration (PE) maintained the moisture availability throughout the crop growth period. Mary et al*.* (2016) observed that greater soil moisture level provided by subsurface drip irrigation resulted in enhanced nutrient availability in the soil which in turn boosting the nutrient uptake by the crop.

1.6 Irrigation Scheduling

Irrigation scheduling can be described as a systematic approach to allocating irrigation water according to the specific water needs of each crop (ETc) in varying soil and climatic conditions, with the objective of maximizing crop production per unit of water applied over a given area within a set timeframe.

Irrigation scheduling is a recurring decision-making process within each year, determining the optimal timing and quantity of water application. Both criteria influence the quantity and quality of the crop. It indicates the quantity of irrigation water to utilize and the frequency of application. Various methods of irrigation scheduling have been used and each one with its own unique strengths and weaknesses.

1) **Soil moisture depletion strategy:** The existing soil moisture within the root zone serves as a reliable parameter for irrigation scheduling. As the soil moisture within a defined depth of the root zone reaches a specific threshold, varying for each crop, it necessitates replenishment through diverse irrigation methods.

These approaches are reliable, but they may not be advisable for farmers because due to the limited availability of tools for analyzing soil water content or soil moisture tension.

2) **Plant indices:** Plants can serve as an indicator for scheduling irrigation. The moisture stress in plants will be reflected by dropping, curling or rolling of leaves and change in foliage colour by the plant itself which can be accounted as an indicator for scheduling irrigation. However, while these symptoms signal the requirement for water, but they don't allow for precise quantitative assessment of moisture deficit.
3) **Climatological approach:** Evapotranspiration is primarily influenced by climate conditions. Estimating the water loss through evapotranspiration relies on climatological data, and irrigation is scheduled when evapotranspiration reaches a specific threshold. The irrigation amount is determined either as equivalent to evapotranspiration or as a fraction of evapotranspiration. Various methods within the climatological approach include the IW/CPE ratio method and the pan evaporimeter method.

In the IW/CPE approach, a predetermined quantity of irrigation water is applied once the cumulative pan evaporation (CPE) reaches a predetermined threshold. With the IW/CPE ratio method, irrigation can also be scheduled at specific CPE levels by adjusting the quantity of irrigation water. It can be considered as deficit irrigation as the irrigation interval is same, but quantity of water given is reduced. But the equipment to measure the pan evaporation and irrigation water are not available with the farmers.

In pan evaporimeter method, small cans of one litre capacity are used to indicate evaporation from the cropped field. Irrigation is planned when the water level in the containers drops to a predetermined point.

4) **Critical growth approach:** In every crop, certain growth stages are susceptible to irreversible yield loss due to moisture stress. These stages are termed critical periods or moisture-sensitive periods. If there is an ample supply of irrigation water, irrigation is planned whenever the soil moisture drops to the critical level.

1.7 Impact of Various Irrigation Scheduling in Different Aspects of Fodder Crops

Patel et al. (2010) reported that frequent irrigations at IW: CPE ratio of 1.0 increased the height of plant and leaf stem ratio in fodder oats. Rathod et al*.* (2023) studied the response of summer fodder maize (*Zea mays* L.) to different irrigation levels and reported that IW: CPE of 1 recorded the highest plant height and number of leaves per plant. Shivakumar et al. (2011) reported that irrigation at an IW/CPE ratio of 1.0 produced higher total green fodder yield (43.5 t ha^{-1}) and drymatter yield (75.6 g $plant^{-1}$) compared to 0.6 IW/CPE (24.1 t ha^{-1} and 43.9 g $plant^{-1}$, respectively) in baby corn. Vennila and Ananthi (2019) reported that the yield was found to be higher with the application of FYM 25 t ha^{-1} + 100 per cent recommended dose of fertilizers (RDF) and drip irrigation at 100 per cent potential evaporation (PE). Varshini and Jayanthi (2022) conducted a study on different irrigation methods like surface, subsurface drip, surface drip and micro irrigation in BN hybrid and the result indicated that higher green (335 t ha^{-1} yr^{-1}) and dry (71 t ha^{-1} yr^{-1}) fodder yields were recorded by subsurface drip irrigation.

Vennila and Ananthi (2019) reported that crude protein content of the BN hybrid was significantly affected with the irrigation and nutrients levels. Varshini and Jayanthi (2020) reported that subsurface drip irrigation in bajra napier hybrid grass reported higher phosphorous (29.8 kg ha^{-1}), potassium (88.2 kg ha^{-1}) and nitrogen (157.4 kg ha^{-1}) uptake. This was mainly because subsurface drip irrigation promptly provided soil moisture, which facilitated increased dry matter production and consequently improved nutrient absorption (Sathya et al., 2008). Patel et al. (2013) studied different irrigation scheduling in pearl millet fodder production, and the findings indicated that an irrigation schedule of 0.6 IW/CPE ratio achieved a greater WUE of 10.2 kg ha^{-1} mm^{-1} compared to ratios of 0.8 and 1.0 9.1 and 8.5 kg ha^{-1} mm^{-1}, respectively). The WUE decreased with each subsequent rise in the IW/CPE ratio. Rathod et al. (2023) found that the IW/CPE ratio of 1 recorded the highest gross returns, net returns, and B:C ratio.

2. CONCLUSION

Addressing the challenges of fodder production in India is essential for enhancing the livestock sector, which is vital for the livelihoods of many rural communities. With livestock productivity significantly lower than the global average, primarily due to inadequate feeding practices and limited access to high-quality fodder, urgent action is required to bridge the gap between demand and supply. Innovative practices, such as the implementation of effective irrigation scheduling and the adoption of advanced irrigation technologies like drip and sprinkler systems, are crucial for enhancing water use efficiency and boosting fodder crop productivity. Furthermore, increasing the cultivation of high-quality fodder varieties, optimizing management practices, and promoting research and development in fodder crop production will be essential for bridging the gap between demand and supply. Ultimately, a concerted effort among farmers, policymakers, and agricultural researchers is necessary to transform the fodder sector, ensuring food security for both livestock and the communities that depend on them.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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