__Review Article__

Exploring the Nutritional Landscape: A review of Fodder options for Livestock

Abstract

Livestock nutrition plays a crucial role in ensuring the health and productivity of animals. Fodder are key component of livestock diets, providing essential nutrients for growth, reproduction, and overall well-being. The application of inorganic nutrients with the combination of organic nutrients leads to improve crop yield with improvement in soil health and its productivity without deteriorating the environmental conditions. This review aims to explore the nutritional landscape of fodder and forage options for livestock, examining their composition, availability, and potential benefits.

Keywords: fodder, livestock, FYM, RDN

1. INTRODUCTION

Fodder crops, which are utilized to nourish livestock such as cattle, goats, sheep, horses, pigs, and chickens, thrive in well-drained areas with moderate to high rainfall during their growth phase. These crops exhibit resilience in acidic and waterlogged conditions. With their ability to be cut multiple times, fodder crops reduce feeding costs for livestock while generating income. Additionally, they effectively prevent soil erosion and enhance soil health by enriching the soil with organic matter. Given the financial constraints faced by Indian farmers, economical fodder crops like Teosinte are commonly employed to feed animals, enabling cost reduction. As the demand for milk continues to rise with the growing human population, dairy production presents a lucrative opportunity for farmers to increase their income alongside crop cultivation. Meeting the increased milk demand becomes a challenge, making it crucial to provide cattle with highly nutritious feed to maximize their productivity. According to government data, milk demand was 146.3 million tonnes in 2014-15, escalating to 198.4 million tonnes in 2019-20. A study by the National Dairy Development Board (NDDB) predicts a further increase to 266.5 million metric tonnes in milk and its derivatives. Therefore, offering superior quality feed to animals ensures optimal milk yield and quality. The excessive use of synthetic fertilizers in agriculture has led to environmental pollution. To cultivate high-quality fodder crops without harming the environment, the adoption of Integrated Nutrient Management (INM) is imperative. INM involves the strategic use of organic, inorganic, and biological components to improve soil fertility and supply essential nutrients to plants. This practice enhances the physical, chemical, and biological properties of the soil, while also boosting the availability of both native and applied nutrients. By implementing INM, sustainable agriculture can be promoted, ensuring minimal negative impact on the environment caused by chemical fertilizers. The annual application of organic matter to the soil enhances soil conditions by improving its structure, increasing soil CEC (Cation Exchange Capacity), expanding nutrient availability, boosting humus content, and providing a conducive environment for microbial activity [11]. Nitrogen is a vital component of proteins, nucleic acids, enzymes, coenzymes, chlorophyll, and cell walls, playing a crucial role in various biological processes. Phosphorus is also essential for crop production, participating in CO_2 fixation, sugar metabolism, energy storage, and transfer [73].

2.THE EXISTING SITUATION OF FODDER PRODUCTION IN INDIA

The production of fodder crops in India exhibits regional variations, influenced by factors such as cropping patterns, socio-economic conditions, and the specific livestock being raised. These crops serve as feed for animals in various forms, including dehydrated hay, anaerobically preserved silage, and fresh green forage. Egyptian clover (1.9 million hectares) and Sorghum (2.6 million hectares) account for 54% of the total cultivated area in India [17]. Currently, there is a significant deficit of 35.6% in green feed, 10.95% in dry forage, and 44% in concentrate feed materials [31]. By the year 2050, the demand for dry feed and green fodder is projected to be 631 and 1,012 million tonnes, respectively (Fig. 1). Considering the current rate of forage supply expansion, there will be a shortfall of 13.2% in dry fodder and 18.4% in green fodder by 2050. To bridge this gap, the production of green fodder needs to increase at a rate of 1.69% annually. However, only 4% of the total cultivated area (8.4 million hectares) is currently dedicated to fodder cultivation in India [17, 50].

3. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN OATS (*Avena Sativa* L.)

OAT, scientifically known as *Avena sativa* L., is a winter crop belonging to the *Avena* genus. It is widely used as animal feed, available in the forms of green fodder, straw, hay, or silage.

Oat grains are notable for their high dietary fiber content and serve as a valuable protein source, typically containing 10-12 percent protein and 30-35 percent dry matter. This makes oats a suitable food for various livestock, including cattle, sheep, and poultry. Optimal growth conditions for oats involve cool and moist weather, with a temperature range of 15-25 degrees Celsius. Notably, oat cultivation following kharif rice can result in significant nutrient uptake. Roy et al. conducted a study [58] that recommended using 50% of the recommended dose of fertilizer (RDF) and applying 10 tons per hectare of farmyard manure (FYM) to achieve enhanced nutrient uptake and crop yield. Based on these findings, it is advisable for farmers to consider cultivating oats after kharif rice and applying 50% RDF and 10 tons per hectare of FYM. Incorporating organic fertilizers like vermicompost and FYM, along with controlled application of synthetic fertilizers such as RDF, can positively impact crop yield and quality. However, it is essential to note that these recommendations are specific to single-cut oats and may not be universally applicable to other crops [44]. The researchers suggest that the application of 5 tons per hectare of vermicompost, 5 tons per hectare of farmyard manure (FYM), and 50% nutrient application from RDF result in higher yield and quality fodder from single-cut oats. Farmers and agricultural practitioners could be advised to consider employing a combination of organic and inorganic fertilizers to enhance the productivity and quality of their fodder crops. It is important to acknowledge that the specific blend and quantity of organic and inorganic sources may differ based on the crop type and local soil conditions. Therefore, consulting with experts and conducting soil testing before applying fertilizers is recommended. The suggestion finds support from studies conducted by researchers [50, 5]. It can be concluded that utilizing a combination of organic and inorganic fertilizers can result in higher yields and improved fodder quality. Meena et al. [50] demonstrated that a combination of vermicompost and sheep manure yielded maximum protein production, as well as higher dry and green fodder yields. Similarly, Backiyavathy et al. [5] observed that a combination of vermicompost and 75% of the recommended dose of inorganic fertilizer resulted in optimal green and dry fodder yields. Another suggestion for farmers and agricultural practitioners is to consider applying the appropriate levels of nitrogen (N) and phosphorus (P) for efficient green fodder production. Soil testing and analysis can assist in determining the specific nutrient requirements of crops, aiding in informed decision-making regarding fertilizer selection. It is crucial to note that excessive fertilizer use can have detrimental effects on the environment, including soil degradation and water pollution. Therefore, responsible and judicious fertilizer application is essential. A study investigating the impact of different nitrogen (N) and phosphorus (P) levels on green fodder yield found that applying 150 kg N/ha and 60 kg P/ha resulted in the highest yield of 74.67 t/ha compared to other treatments [3]. These findings highlight the significance of nitrogen and phosphorus as vital nutrients for green fodder production, emphasizing the importance of optimal levels to achieve increased yields. Utilizing beneficial microorganisms in conjunction with optimal fertilizer application to enhance the growth and yield of oats and other crops is recommended. It is worth emphasizing that conducting soil testing and analysis can assist in determining the specific nutrient requirements of crops, facilitating crucial decisions regarding appropriate fertilizers and microbial treatments. The inclusion of advantageous microorganisms like Azotobacter and PSB (phosphate solubilizing bacteria) can enhance the growth and yield of oats, as well as improve nitrogen utilization efficiency. Treating oat seeds with Azotobacter and combining them with 40 kg N/ha resulted in the highest nitrogen utilization efficiency [65]. Deva (2015a) observed a significant increase in the population of soil bacteria, actinomycetes, and fungi when PSB and Azotobacter were used in conjunction with the recommended fertilizer dose [21]. The combination of Azotobacter and oat seeds led to increased tillers, plant height, and dry matter yield of the fodder crop, indicating the potential for nitrogen fixation [22]. Incorporating bio-fertilizers (Azotobacter + PSB) alongside 100% of the recommended fertilizer dose (RDF) can lead to increased yield of green and dry fodder. Furthermore, the study revealed that this combination also yielded the highest benefit-to-cost (B:C) ratio, demonstrating the economic viability of this approach. Based on these findings, it is suggested to utilize a combination of bio-fertilizers and RDF to enhance crop yield and economic viability [23].

4. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN BERSEEM (*Trifolium alexandrinum* L.)

Berseem, a winter forage crop grown in various countries worldwide, holds significant importance. It possesses high nutritional value, with approximately 20% crude protein and 70% dry matter content. Moreover, Berseem is an abundant source of essential minerals like calcium and phosphorus. Cultivating berseem aids in loosening compact soil, improving soil aggregation, and enhancing chemical properties such as nitrogen, organic carbon, and available phosphorus. Furthermore, it aids in the suppression of weed growth. Enhance plant growth and foster plant development by employing a combination of fertilizers and organic sources like poultry manure and farmyard manure. The synergistic impact of incorporating organic sources such as poultry manure and farmyard manure with fertilizers positively influences plant growth and development. Specifically, the utilization of a mixture consisting of 75% recommended fertilizer dose along with 25% nitrogen obtained from poultry manure, and the application of 75% recommended fertilizer dose with 25% nitrogen derived from farmyard manure, yielded the highest number of nodules per plant [45]. Introducing farmyard manure into a rice-berseem cropping system can also contribute to enhanced crop yield. The application of 10 tons per hectare of farmyard manure in a rice-berseem cropping system, along with 100% recommended doses of nitrogen, phosphorus, and potassium, led to increased green yield of fodder berseem and rice yield [6]. This finding indicates that the use of farmyard manure can be advantageous in enhancing crop yield in a rice-berseem cropping system. It is advisable to adopt the recommended nutrient application doses to achieve better yield and quality of fodder crops. Adequate fertilization plays a pivotal role in the growth and development of forage crops, and it is crucial to meet the crop's nutrient requirements for achieving optimal yield and quality. The study conducted by researchers demonstrated that the implementation of the recommended nutrient dose led to higher yields of green foliage, dry matter, and crude protein in berseem compared to other treatments [9]. Similarly, another study concluded that applying the recommended dose of fertilizer is essential for achieving higher yields of green fodder and dry matter [74]. Employing a combination of organic and inorganic fertilizers can positively influence the growth of berseem crops. Specifically, implementing 50% of the nitrogen requirement through farmyard manure and the remaining 50% through inorganic nutrients resulted in improved growth parameters [28]. Enhancing the protein and ash content and improving the fiber quality of the crop can be achieved by inoculating the seeds with rhizobium and utilizing a combination of organic and inorganic fertilizers, including nitrogen. The study supported this suggestion and found that the inoculation of seeds with rhizobium and the application of 25kg N/ha together can increase the crude protein and ash content of the crop, significantly impacting the acid and neutral detergent fiber [60]. For berseem, the application of 30kg N/ha and cutting at a 5cm stubble height yielded the highest forage output. Additionally, the highest yield of berseem (60t/ha) was observed when basal application of 20kg N/ha was followed by an additional 10kg N after the first cut [7]. Based on these findings, it is recommended that farmers and agricultural practitioners consider employing this application and cutting methods to maximize the yield of berseem in their fields.

5. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN SORGHUM (*Sorghum bicolor* L.)

Sorghum ranks fourth as a major food grain globally and third as a major food grain crop in our country. It serves as a vital food source for millions of people in Africa and Asia. Apart from being a staple food for humans, it is also an excellent source of cattle feed and fodder. Sorghum has a protein content of 10-12%, fat content of 3%, and carbohydrates content of 70%. This makes it suitable for feeding dairy cattle, poultry, and swine. Its well-developed root system, which is more fibrous than maize, makes sorghum a valuable crop. Some introduced fodder varieties of sorghum are even juicier and sweeter than grain varieties. The application of 2.0 tons of castor cake per hectare had a significant positive impact on various parameters, such as leaf count, leaf-to-stem ratio, stem diameter, and nutrient uptake. Additionally, the sorghum in the treatment group that received castor cake exhibited higher protein content [52]. Inoculating Azospirillum bacteria can enhance the yield of both green and dry fodder of sorghum. Moreover, the application of 25% nitrogen through farmyard manure (FYM) in conjunction with 75% of the recommended dose of fertilizer (RDF) and Azotobacter proved to be a viable treatment for increasing the yield of both green and dry matter in comparison to other treatments. Another study demonstrated that the application of 15 tons per hectare of FYM alone resulted in an elevation of the crude protein content in sorghum [42]. In the Udaipur region of Rajasthan, the application of an inorganic source consisting of 80kg of nitrogen per hectare positively influenced the growth and yield of summer fodder sorghum. This nitrogen level led to increased plant height, stem diameter, dry matter production, and number of leaves per plant, all of which are crucial indicators of yield quantity and quality [66]. Adopting 125% of the recommended dose of fertilizer (RDF) represents an effective strategy for maximizing crop growth and yield in the Udaipur region of Rajasthan. This level of nutrient application yielded the highest values for plant height, stem girth, leaf-to-stem ratio, leaves per plant, and dry matter accumulation compared to lower RDF levels [68]. However, it is essential to consider the economic and environmental sustainability when employing high levels of fertilizers, as excessive nutrient application can have adverse effects on soil health, water quality, and greenhouse gas emissions.

6. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN PEARL MILLET (*Pennisetum typhoides* L.)

Pearl millet, also known as "bajra," is a significant crop that serves as a staple food for the less fortunate. Pearl millet is widely cultivated across Africa and Asia and serves as the primary millet crop in India owing to its ability to withstand adverse weather conditions, thus making it a highly drought-tolerant crop. In terms of nutritional value, pearl millet surpasses sorghum, boasting 11.6% protein, 5% fat, 67% carbohydrates, and 2.7% minerals. It is commonly consumed in the form of "chapatis" and is also utilized as a valuable source of green fodder for cattle and feed for poultry. The versatility of pearl millet makes it valuable for both human and animal consumption. The study's findings indicate that the combination of poultry manure or cow dung with biofertilizers has a significant impact on plant growth parameters. The findings of their study indicate that the utilization of these fertilizers in conjunction resulted in the highest measurements of plant height, tiller count, shoot biomass, and root biomass. This research brings attention to the potential benefits of combining organic and biofertilizers in order to optimize plant growth and maximize yield [1]. It suggests that such combinations can serve as viable and advantageous alternatives to synthetic fertilizers, which can have adverse impacts on the environment and human well-being. Moreover, the adoption of organic and biofertilizers contributes to the promotion of sustainable agriculture practices by enhancing soil health and reducing dependency on chemical fertilizers. Farmers and individuals involved in agriculture can derive advantages from these findings by incorporating the combined use of organic and biofertilizers to improve soil health and embrace sustainable farming methods. By incorporating organic manure, farmers and agricultural practitioners can enhance soil health, boost crop yield, and reduce the reliance on synthetic fertilizers, which can have adverse effects on the environment and human health. The researcher concluded that the drilling method of vermicompost application is more effective compared to incorporation [51]. The study found that drilling 2.0t/ha of vermicompost resulted in improved tillers, longer ear length, and increased seed production. Similarly, the study revealed that applying 50% of the recommended dose of fertilizer (RDF) and the remaining 50% of nitrogen through organic manure can enhance soil health and crop yield. This method increased the soil organic carbon content and improved the availability of nitrogen, phosphorus, and potassium in pearl millet-pigeon pea cropping systems [75]. The higher levels of nitrogen, phosphorus, and potassium present in poultry manure compared to other organic nutrient sources may contribute to its effectiveness in improving soil health and crop yield. The combination of different types of organic manure can have synergistic effects on promoting soil health and fertility. The combination of synthetic and organic fertilizers can be effective in promoting plant growth and improving crop yield. Implementing 75% of the recommended dose of fertilizers along with 10 tons per hectare of farmyard manure can result in higher plant height in fodder bajra [46]. There is a potential benefit in using a combination of synthetic and organic fertilizers to enhance crop yield and productivity. By using optimal amounts of synthetic fertilizers and supplementing them with organic sources such as farmyard manure, farmers can foster plant growth while reducing the use of synthetic fertilizers. Moreover, nitrogen fertilizer application can significantly impact the yield of pearl millet, highlighting the importance of using appropriate amounts of fertilizers for different crops. It was found that applying an additional nitrogen rate of 120kg N/ha led to an increase in forage yield of pearl millet [30]. This indicates the significant influence of nitrogen fertilizer on the yield of pearl millet, a crucial crop in many agricultural systems. Researchers conducted a field trial to investigate the impact of integrated nutrient management on soil fertility under pearl millet, recording the maximum and minimum values of nitrogen, phosphorus, potassium, and carbon, which are essential nutrients for plant growth [34].

7. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN COWPEA (*Vigna sinensis* L.)

Cowpeas, also known as 'lobia,' are a versatile crop with multiple uses, including fodder, pulses, and green manure. They are often referred to as "vegetable meat" due to their high protein content and essential nutrients. Cowpeas are a rich source of calcium and iron, containing approximately 23.4% protein, 1.8% fat, and 60.3% carbohydrates. The nutritional value of cowpeas underscores their potential as a valuable food source and their importance in crop production systems. Cowpeas are consumed by both humans and animals. They have better forage quality for cattle compared to lucerne. Cowpeas are a promising green manure crop as they exhibit substantial vegetative growth and help prevent soil erosion by acting as a cover crop. Enhancing the growth and yield of cowpea plants can be achieved by using microbial inoculants and organic fertilizers such as vermicompost and biofertilizers. This approach can reduce reliance on synthetic fertilizers, which can have adverse environmental impacts and be expensive for farmers. Moreover, the use of these organic inputs promotes sustainable agricultural practices and supports soil health and surrounding ecosystems. The application of microbial inoculants like Rhizobium, Phosphobacteria, and Azospirillum can positively affect the yield and growth of cowpea plants. The combination of these three microbial inoculants resulted in a higher number of pods in cowpea [62]. Similarly, the research conducted by Mundra and Bahti demonstrated that the inoculation of rhizobium increased the number of nodules per plant, indicating improved plant growth and development [38]. The application of vermicompost resulted in increased cowpea yield compared to the treatment without vermicompost, while the use of biofertilizer led to an increase in dry matter production compared to the absence of biofertilizer [2]. Incorporating vermicompost is advantageous as it generally enhances the fresh and dry weight of cowpea plants, ultimately increasing their yield [36]. Adopting a combination of organic inputs and microbial inoculants can enhance the growth and yield of cowpea plants while reducing reliance on synthetic fertilizers. This approach is more sustainable and cost-effective for farmers and agricultural practitioners, leading to greater profitability and environmental benefits. The application of 75% of the recommended dose of fertilizers in combination with Rhizobium, vermicompost, and PSB (phosphate-solubilizing bacteria) resulted in higher numbers of branches and leaves per plant, increased plant height, and greater numbers and sizes of pods [19]. Moreover, this approach was found to be more effective compared to the application of the recommended dose of fertilizers alone, while also reducing the use of inorganic compounds by 25%. Similarly, Thomas and Lal (2002) discovered that the combination of farm compost and vermicompost with inorganic fertilizers led to the highest forage yield of cowpea plants. They also found that the application of phosphorus through PSB and Rhizobium, or a combination of PSB with cow urine foliar sprays, was effective. Applying 20kg N/ha through inorganic nutrients along with rhizobium inoculation resulted in the highest pod weight, shell fresh weight, number of leaves, branches, and yield of green pods in cowpea plants [37].

8. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN BARLEY (*Hordeum vulgare* L.)

Barley, a significant cereal crop belonging to the Gramineae family, serves as an important food source for people residing in cold semi-arid tropics. Barley flour is commonly used to make 'chapatis' and the grain itself contains 11.5% albuminoids, 74% carbohydrates, 1.3% fat, and 12.5% moisture. Roasted barley grain is utilized for making 'Satu' and is extensively used as feed for poultry and livestock in India. Furthermore, barley finds application in the production of beverages such as beer, whisky, brandy, and others. A study indicated that applying 100% recommended dose of nitrogen (RDN) significantly enhances plant height, nitrogen, phosphorus, and potassium content in both straw and grains of pearl millet. It also leads to increased dry matter accumulation and chlorophyll content. Additionally, the study observed that treating the crop with nano-urea as a foliar spray (4ml/l of water) at 30th and 45th days showed similar improvements compared to the control and the application of the same dose of nano-urea at only 30th day [63]. Employing a combination of organic and inorganic fertilizers alongside biofertilizers can result in higher crop yields and improved plant growth. Specifically, using 75% NPK in conjunction with 5 tons of farmyard manure

(FYM) per hectare and biofertilizer yielded higher grain and straw output, as well as improved spike length, number of spikelets per spike, and grain weight per spike in barley [68]. This highlights the significance of utilizing a combination of various fertilizers and biofertilizers to achieve optimal crop production. Applying 75% recommended dose of fertilizer (RDF) in combination with FYM demonstrated the highest field productivity in barley, a productivity similar to that achieved by combining 75% RDF with FYM and biofertilizer [55]. The utilization of farmyard manure (FYM) at a rate of 10 tons per hectare can yield significant improvements in crop productivity, as indicated by the increased number of effective tillers per meter of row length, number of grains per spike, spike length, straw yield, and biological yield [21]. These findings emphasize the potential of organic fertilizers like FYM as a viable substitute for synthetic fertilizers, particularly in sustainable agricultural practices. Moreover, the study underscores the importance of appropriate nutrient management in crop production and highlights the potential advantages of using organic fertilizers to enhance soil fertility and productivity. For farmers and agricultural practitioners aiming to optimize green fodder yield in dual-purpose barley, adopting the two-split nitrogen application method with 2/3 of the nitrogen applied at the basal stage and 1/3 immediately after cutting may be a suitable approach. Alternatively, a three-split nitrogen application method with 1/2 at the basal stage, 1/4 immediately after cutting, and 1/4 at the next irrigation could also be considered as an alternative method [67].

9. INFLUENCE OF THE INTEGRATION OF ORGANIC MANURES AND BIOFERTILIZERS WITH CHEMICAL FERTILIZERS IN MAIZE (*Zea mays* L.)

Maize, ranking third in global significance after wheat and rice, is a highly valued crop known as the "miracle crop" due to its exceptional yield compared to other cereal crops, earning it the title of the "Queen of cereals." Maize serves as a vital food source for both humans and animals, with its grain flour being used in chapati production and its hard corn being a popular choice for popcorn. It is also an excellent feed source for poultry and other livestock. Maize grains contain approximately 2.3% crude fiber, 10% protein, 70% carbohydrates, and 4% oil. Maize crops provide a substantial amount of green fodder for cattle. To improve the growth and yield of maize crops, the application of organic fertilizers such as farmyard manure (FYM) in combination with appropriate doses of chemical fertilizers containing nitrogen, phosphorus, and potassium is recommended. Studies have shown that the combination of organic and inorganic fertilizers is more effective in increasing dry matter production, plant height, and leaf area compared to using chemical fertilizers alone. Additionally, the use of FYM has been found to produce nutritious fodder for animals. Therefore, it is advised that farmers utilize a combination of organic and inorganic fertilizers to enhance crop growth and yield while providing nutritious fodder for their livestock. It is crucial to follow the recommended fertilizer doses and apply them at the appropriate time and in the correct manner to maximize the benefits. This recommendation is supported by a study conducted at IARI, where researchers observed that the application of 120 kg N + 10 t FYM/ha resulted in higher dry matter production and plant height in maize compared to other treatments [35]. Subsequently, researchers found that a combination of 25 t/ha FYM with 100 kg N/ha produced nutritious fodder for animals [53]. In comparison to chemical fertilizers, the application of 10t/ha farmyard manure (FYM) combined with 120 kg nitrogen + 26.2 kg phosphorus + 33.2 kg potassium/ha resulted in higher plant height and leaf area [43]. Utilizing a combination of organic and inorganic fertilizers can lead to increased yields and yield components in maize. Poultry waste can serve as an effective organic nitrogen source, serving as an alternative to chemical fertilizers. The combination of farmyard manure, poultry waste, and urea can contribute to improved yields and yield components in maize. Notably, applying nitrogen from poultry manure, along with a portion from urea, can enhance the harvest index and grain yield of maize. Comparatively, implementing 60 kg N/ha from poultry waste as an organic source, along with 60 kg N, 40 kg P, and 40 kg K/ha from inorganic compounds, resulted in maximum grain and stover yields (8 and 8.9 tons per hectare) [54]. Subsequently, researchers observed that applying an equal proportion of farmyard manure (FYM), poultry waste, and urea at the same amount yielded higher maize yields and yield components compared to the application of either organic or mineral nitrogen alone [4]. Furthermore, applying 50% nitrogen through poultry manure and the remaining amount through urea led to the highest harvest index (24.91%), grain weight per cob (68.98 g), and grain yield of maize (5.6 t/ha) [15], surpassing the results of the unfertilized treatment. Incorporating foliar nutrition can be a beneficial strategy for enhancing crop quality and yield, as evidenced by researchers who found that combining a recommended dose of fertilizer with a single foliar spray of a multi-nutrient solution improved the quality parameter of maize (oil content) [25].

10.IMPACT OF ORGANIC AND INORGANIC NUTRIENT INPUTS ON NUTRIENT ABSORPTION

Using both phosphorus-solubilizing bacteria (PSB) and vermicompost together resulted in a higher uptake of nutrients compared to using either one alone. The combination of 75% recommended dose of fertilizer (RDF), 1 ton/ha vermicompost, and PSB resulted in the maximum uptake of nitrogen, phosphorus, and potassium [20]. When boron, sulphur, and farmyard manure were combined with 75% NPK (N-150, P-60, K-60), the total uptake of nutrients was the highest [56,57]. Organic manure is recognized for its ability to enhance nutrient uptake by solubilizing complex nutrients during decomposition. The decomposition of farmyard manure (FYM) releases organic acids, which increase the availability of phosphorous and promote microbial growth, thereby improving root system growth and phosphorus uptake by plants. Additionally, the combined application of FYM and vermicompost has been shown to enhance phosphorus availability in the soil. Moreover, the decomposition of organic manure releases organic acids that aid in the release of potassium from potassium-bearing minerals in the soil, thereby increasing potassium availability [71].

11. EFFECT OF ORGANIC AND INORGANIC NUTRIENT SOURCES ON REDUCING THE ENVIRONMENTAL POLLUTION AND IMPROVING THE YIELD ATTRIBUTE CHARACTER

Farmers often rely on the intensive use of inorganic fertilizers to maximize their returns. However, the excessive use of inorganic fertilizers has a detrimental impact on both the soil and the environment. To address this issue, the combination of inorganic fertilizers with organic sources has been found to significantly increase crop yield (by 8 to 150%) and improve the economic return for farmers. The principle of integrated nutrient management (INM) focuses on sustainable agricultural practices by incorporating various inputs to enhance soil health. Any degradation in the soil directly affects yield as the soil serves as the primary source of nutrients. Implementing INM practices improves water use efficiency (WUE) and nutrient use efficiency (NUE) in plants, reduces environmental pollution, and ultimately increases yield [77]. Nitrogen is a crucial nutrient essential for enhancing crop yield, and its requirement surpasses that of any other nutrient. The combination of organic and inorganic nutrients has been proven to increase both biomass yield and grain yield [41]. Nitrogen plays a vital role in facilitating the conversion of carbohydrates into proteins, supporting protoplasm formation [12]. Increased nitrogen uptake has been associated with improved yield attributes, resulting in greater dry matter production [18]. Integrating organic and inorganic nutrient sources has also shown positive effects on yield attributing characters such as grains per spike, test weight, and dry matter accumulation [49].

12. EFFECT OF ORGANIC AND INORGANIC NUTRIENT SOURCES ON SOIL PRODUCTIVITY

Integrated Nutrient Management (INM) is a holistic approach that integrates the use of both inorganic and organic sources of nutrients, as well as biological processes, to enhance crop yield [33]. Organic matter plays a pivotal role in this strategy as it improves nutrient availability, enhances water retention capacity, and provides an ideal environment for plant growth and development. Moreover, organic matter contributes to improving soil physical properties such as bulk density, porosity, and water holding capacity [8]. The application of manure not only boosts the yield for the current season but also enhances nutrient availability for subsequent seasons. Studies indicate that the integration of diverse nutrient sources, including chemical fertilizers, farmyard manure, compost, organic manure, and biofertilizers, improves soil infiltration rate, reduces bulk density, and enhances soil organic matter content, aggregate stability, and moisture retention capacity [59]. The organic matter content in the soil can increase from 28.6% to 35.7%, and the efficacy of inorganic fertilizers is enhanced through favorable soil microbial activity and the enrichment of soil colloids, which provide a large surface area for nutrient retention [47]. Additionally, combining chemical fertilizers with organic fertilizers can alleviate deficiencies in secondary and micronutrients [13].

13. CONCLUSION

In summary, the adoption of integrated nutrient management offers numerous advantages for soil and plant health. The reliance on chemical fertilizers in fodder crop production can have detrimental effects on the soil, including increased acidity and chemical residue accumulation. Integrated Nutrient Management emerges as the optimal solution to address these concerns, providing benefits such as improved crop yields, enhanced nutrient uptake, environmental sustainability, cost-effectiveness, and enhancement of soil fertility and quality. This approach also helps mitigate the adverse environmental consequences associated with chemical fertilizers. Research studies have consistently demonstrated that the combined application of organic and inorganic nutrients leads to favorable outcomes in terms of growth parameters, yield, disease control, and microbial activity in the soil. Additionally, the continuous cultivation of crops using a combination of organic and inorganic nutrients promotes increased grain yield and enhances overall soil productivity and health. Hence, Integrated Nutrient Management can be unequivocally regarded as the most effective strategy to boost crop yield and ensure soil health without compromising the environment.

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