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Nutrient Management for Optimizing Fodder Production of Sorghum – A Review

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ABSTRACT

An area under cultivation of fodder crops has almost remained static (8.3 million ha) for the last 3 decades and area under permanent pastures has been declining over the years. Whereas, uncontrolled overgrazing reduced productivity of permanent pastures. Overgrazing also affect the soil bio-physic-chemical properties. The situation is further aggravated due to increasing human population and preferential need for food and growing commercial crops. In India, supply of forage has always been a limiting factor for enhancing livestock production. Demand of green and dry fodder continuously increasing as enhancing country's livestock population. The gap in feed and forage supply, however, can effectively be reduced through integrated crop management practices with greater emphasis on nutrient management in forage crops. Application of nitrogen increases crude protein, digestible dry matter content and metabolic energy. Growth attributes with respect to plant height, stem diameter, Leaf Area Index (LAI) and number of basal node tillers increased with increase of phosphorus application levels. Application of micronutrients improves enzymatic activities and it leads to increase growth and yield of the fodder sorghum. Review regarding the use of adequate and optimum dose of nutrients especially nitrogen, phosphorus and micronutrients are of prime concern for the fodder sorghum crop in India. Keeping these points in view, the literature reviewed pertaining to the nitrogen, phosphorus and micronutrients in this crop to obtain higher biomass and good quality fodder production.

KEYWORDS: Crude fiber, fodder growth, micronutrients, macronutrients, nitrogen, sorghum

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1. INTRODUCTION

Now a day, the country is facing a net shortfall of 35.6% green fodder, 10.5% dry crop leftovers, and 44% concentrate feed ingredients (Singh et al., 2022). Livestock is the sub-sector of agriculture and contributes around 32% in agricultural output. Country accounts 15% of the World's livestock population and only 2% of the World's geographical area is resulting into high livestock pressure on the limited land resources (Day and Kumar 2017; Sarvade et al., 2019). It results in lowering the livestock productivity. Sorghum, bajra and maize are the main *kharif* fodder cereal crops. Whereas, berseem and oat are the main *rabi* fodder crops.

Sorghum [*Sorghum bicolor* (L.) Moench], belongs to family of *Poaceae*, is the king of millets and ranks third in major cereal crops in the country after rice and wheat (Chaudhary et al., 2018). Fodder sorghums are usually classified into forage sorghums, Sudan grasses and sorghum- Sudan grass hybrids. It has ability to tolerate heat, drought and withstand under water logging condition than other cereal fodder crops. Due to its fast growing habit, quick re-growth, higher biomass production potential, provides palatable and succulent nutritious fodder to the livestock. This fodder crop is extensively grown in Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Gujarat, Tamil Nadu, Rajasthan, Uttarakhand and Uttar Pradesh states. Imbalance application of fertilizer to the fodder sorghum results in poor yield and quality. However, sorghum is a nutrient exhaustive crop, which needs proper application of fertilizer for enhancing the productivity and fodder quality. Nutrient management practice in fodder sorghum has widely been described by various researchers (Yadav et al., 2010, Meena et al., 2013, Prajapati and Kewalanand, 2019). Ramanjaneyulu et al. (2012) reported that the fodder yield of sorghum with an application of recommended dose of fertilizers (RDF, 60 kg N+12.9 kg P ha^{-1}) and half RDF+bio-fertilizers on fresh and dry weight basis was statistically superior to half RDF.

Nitrogen is the most important nutrient for plant growth and is the most limiting nutrient in Indian soils. It is an essential constituent of protein, nucleic acid, nucleotide, chlorophyll, phospholipids, alkaloids, enzymes and hormones. Application of nitrogen increases crude protein, digestible dry matter content and metabolizable energy. Phosphorus is second most deficient major essential plant nutrients after nitrogen (Munir et al., 2004). Phosphorus plays an important role in photosynthesis and synthesis of nucleic acids, lipids, proteins and other important compounds (Guinn, 1984). Application of phosphorus fertilizer gradually increase plant height, stem diameter, number of leaves per plant, leaf area and fodder yield (Khalid et al., 2003). Zinc has metabolically important role in plant growth and development and therefore called an essential trace element. It took part in the synthesis of proteins, enzyme activation, oxidation and revival reactions as well as metabolism of carbohydrates. Soil application of zinc sulphate increases zinc content in sorghum fodder (Muthusamy et al., 2022). Similarly, boron increases growth, boosts tolerance against stress and improves crop yields. Whereas, synthesis of chlorophyll and protein, photosynthesis, electron transfer, oxidation and reduction of nitrates and other enzymatic activities in plants controlled by availability of iron (Singh et al., 2011, Ali et al., 2014). Adequate fertilization in terms of macro and micronutrients is essential to ensure the quantity and quality of green fodder. Therefore, the judicious application of nutrients in the sorghum fodder crop helps to increase its productivity (Nirmal et al., 2016). This paper aimed at to review the impacts of the applications of macro and micronutrients on production and productivity of quality fodder sorghum in the last few decades.

2. IMPACT OF N FERTILIZATION ON CROP GROWTH PARAMETERS

Variation in the yield cannot well characterize until they studied in relation to growth contributory traits. Yield of forage crops directly related to the plant height, number of tillers, number of leaves per plant, leaf area index and leaf stem ration. All these growth parameters significantly influenced by nutrients applications, especially nitrogen. The better growth and development of crop takes place under the sufficient availability of soil nitrogen. Nitrogen is the major constituents of the protoplasm that help in the cell formation and elongation due to synthesis of nucleotides and coenzymes. The increasing level of nitrogen leads to increase the nitrogen concentration in the cell sap, and utilized in formation of amino acids, amides and proteins. It improves leaf area index, shoot development, photosynthetic productivity of crop canopy that ultimately leads to dry matter accumulation in the crop plants (Sivasankar et al., 1993).

Dynamics of N in soil profile influenced by both climate and soil texture which influences the growth and development of vegetation. An amount of N removed may be large and in some cases, much more N removed than estimated as being available to the crop in nitrate form. Even if more N mineralized than removed by the crop in a particular season without a net addition of N, and crop production gradually declined due to deficiency of N.

Application of N to the fodder sorghum crop had direct impact on all the morphological attributes of the crop. Increasing levels of nitrogen significantly affect the plant height, number of leaves per plant, leaf area index and fresh and dry matter accumulation in cereal crops (Sarvade et al., 2014a). Further, the crop growth rate and relative crop growth also increased with the nitrogen application. An increase in growth parameters with the application of nitrogen helped in the synthesis of protoplasmic constituent that accelerate the process of cell division, cell elongation, chlorophyll formation and meristematic activity, which increased length of internodes and number of nodes resulted in better growth. Black (1957) reported that plant growth adversely affected more in the deficiency of nitrogen than that of other nutrients.

Uptake of N into above ground plant parts of sorghum was studies at ICRISAT, Hyderabad and reported that the tall and late maturing Indian sorghum cultivar was grown in a low fertility *alfisol* with 20 kg N ha^{-1} added as fertilizer yielded 15 tones dry matter ha^{-1} containing 134 kg N. Sorghum being a cereal crop exhaust more nitrogen than other nutrients hence it needed higher amount of nitrogen (Kushwaha et al., 2018). Nutrient uptake may also depend on the soil condition (Sarvade et al., 2017); it influences quality of the fodder production also (Sarvade et al., 2019). It shows that optimization of nitrogen dose is an important for getting cost effective fodder yield. Mineral nutrition considered necessary for enhancing or promoting growth of crop. Number of researchers has highlighted the importance of nitrogen fertilizer and its accelerating effect on plant height, number of leaves, leaf area, leaf area duration and grain filling (Gahlot et al., 1979, Mehrotra et al., 1979, Neil, 1989, Sarvade et al., 2014a, Sarvade et al., 2014b, Shrivastava et al., 2020). The growth parameters other than Leaf Area Index and stem girth has also increased with increasing rates of nitrogen application from 40 to 120 N ha^{-1} (Desai and Deore, 1980). Information on the rates of nitrogen application in different sites needed to highlight as per soil and climatic conditions. Experiment conducted at Agricultural University, Junagarh, Gujarat by Patel et al. (1990) reported that the application of nitrogen @ 150 N ha^{-1} significantly improved the phenological traits of sorghum like height of plant, productive shoots/plant, dry matter accumulation/plant in *rabi* season under clay soils. The study of carried out by Mustafa (1995) on Sudan grass and found that the plant height and Leaf Area Index significantly increased with the increasing in dose of nitrogen from 43 to 129 kg ha^{-1}. Finding of Singh et al. (1996) reported that the 100 kg of nitrogen is significant to get luxurious growth of sorghum at Pantnagar under silty clay loam soil. Similar result of various studied conducted at different places indicate that 100–150 kg N ha^{-1} is sufficient and gave desire results with respect to development of plants in term of phenology (Nirmal et al., 2016, Chaudhary et al., 2018). Increasing level of nitrogen from 60 to 120 kg N ha^{-1} progressively increased the growth of plant in terms of height and side shoots in first, second and third cuttings. It also improves the leaf: stem ratio of crop (Crawford et al., 2018).

3. IMPACT OF N FERTILIZATION ON YIELD AND YIELD ATTRIBUTES

Increasing level of nitrogen from 40 to 80 kg ha^{-1} progressively increased the green fodder, dry fodder and crude protein (Rathod et al., 2002, Dhar et al., 2003, Shiva et al., 2005). Singh et al. (2005) reported that application of 100 kg N ha^{-1} resulted in high yield of sweet and forage sorghums. Experiment conducted by (Ayub et al., 1999) at Faisalabad, Pakistan and reported that nitrogen applied up to 100 kg N ha^{-1} recorded significantly higher dry matter yield (1568 kg ha^{-1}) than without nitrogen and 50 kg N ha^{-1}. Similarly, Singh et al. (2015) observed that application of 100 kg N ha^{-1} produced significant highest green fodder (495.11q ha^{-1}) and dry fodder yield (173.81 q ha^{-1}) which was statistically similar to 80 kg N ha^{-1}. Further Shinde et al. (1987) reported that three sorghum varieties viz. S–136, Pusa Chari–6 and MP Chari gave averaged fresh fodder yield of 88.91, 70.00 and 59.79 t ha^{-1}, respectively, in three cuttings with 160 kg N ha^{-1}. Research finding of various workers revealed that the application of nitrogen 150–160 kg N ha^{-1} significantly increased fresh stalk, juice, green herbage, dry fodder, crude protein and digestible dry matter yield, might be due to increased cell division, enlargement and chlorophyll synthesis resulting in better growth (Nazir et al., 1997, Verma et al., 1994, Saheb et al., 1997).

Application of nitrogen fertilizer ranges from 30 to 120 kg N ha^{-1} progressively increased the green herbage, dry fodder and crude protein yields. The application of 120 kg N ha^{-1} gave significantly higher green forage, dry matter and crude protein yields over 30, 60 and 90 kg N ha^{-1} (Shukla and Sharma, 1994, Bhilare et al., 2002). Experiment conducted by Verma et al. (2005) and Chandra and Joshi (2006) at Pantnagar (Uttarakhand) observed that the green fodder, dry matter, crude protein and digestible dry matter yield were significantly higher by application of 120 kg N ha^{-1} as compared to 0, 40 and 80 kg N ha^{-1}, respectively. Similarly, Crawford et al. (2018) from Anand, (Gujarat) reported that application of 120 kg N ha^{-1} gave significantly higher green fodder and dry fodder yield over 60, 80, 100 kg N ha^{-1}, respectively. Further Manjunatha et al. (2013) reported that the multi-cut sorghum variety (COFS–29) produced significantly higher dry fodder yield (42.33 t ha^{-1}) with application of 300 kg N ha^{-1} over 120, 180 and 240 kg N ha^{-1}.

4. IMPACT OF N FERTILIZATION ON QUALITY TRAITS

Forage quality includes traits that makes the forage valuable to animals. Forage quality defined as the capacity to supply and fulfill the animal nutrient requirements. It includes the acceptability or liking of animals towards forage composition with respect to chemical and physical traits as well as the digestibility of nutrients. Quality fodder have the special features and characteristics like animals are able to consume and digest, and provide the needed nutrients for growth and good health. Forage quality possesses to the potential to produce milk, meat or wool. Various parameters used to describe the forage quality are crude protein, ash content, relative feed value, hemicellulose, ADF (acid detergent fibre) and NDF (neutral detergent fibre) contents. Walli and Relwani (1970) studied conducted at NDRI, Karnal (Haryana) and reported that the crude protein content, crude fibre, calcium and phosphorus had linear correlation with nitrogen application. Similarly, Karwasra and Dahiya (1997) reported that the increase in N content, crude protein and digestible dry matter content increased with increase in nitrogen levels. Succulence of plant enhanced with incremental dose of nitrogen application which positively affects the cell wall and non–cell wall components of the tissues (Van Soest, 1976) and decrease in rate of lignification of cell wall with increase in nitrogen application (Shukla, 1985). Similarly, Ayub et al. (2002) from Faisalabad, Pakistan reported that quality parameter of forage sorghum such as crude protein, ether extract and ash content increased with increase in level of nitrogen application. Maximum content of crude protein and ether extract recorded at 150 kg N ha^{-1} application. However, NDF and ADF content decreased with increase in nitrogen levels. The higher crude protein obtained at application of 120 kg N ha^{-1} over 30, 60 and 90 kg N ha^{-1} (Bhilare et al., 2002). Experiment conducted by Verma et al. (2005) and Joshi et al. (2006) at Pantnagar (Uttarakhand) reported that the dry matter, crude protein content and digestible dry matter content of fodder sorghum increased significantly with increase in levels of nitrogen from 0 to 120 kg N ha^{-1}. Further Habib et al. (2007) concluded that increased N levels enhanced ash content, crude protein content and dry matter digestibility content. Similarly, Singh and Sumeriya (2012) reported that 80 kg N ha^{-1} recorded significantly higher crude protein content, crude fibre, crude fat and ash content over 40 kg N ha^{-1} and control.

5. ROLE OF PHOSPHORUS IN PLANT NUTRITION

Phosphorus considered as second major essential plant nutrients after nitrogen required by plants for their growth and development (Munir et al., 2004). It is, however, one of immobile and unavailable nutrient present in soils (Narang et al., 2000). It is an integral part of nucleic acid and improved the various metabolic as well as physiological processes in the plant system. It plays an important role in storage and transmission of energy. An energy obtained from photosynthesis and metabolism of carbohydrates is stored in the form of phosphate compounds *i.e.* ATP for subsequent use in growth and reproductive process through phosphorylation. Fodder contains 0.35–0.40% P as per the weight of the animal. The 8.1, 13.2, 14.0 and 14.4 g phosphorus required daily for animals having body weight of 100, 200, 300 and 400 kg, respectively (Iqbal et al., 2004).

6. IMPACT OF PHOSPHORUS FERTILIZATION ON GROWTH PARAMETERS

The application of phosphorus fertilizer gradually increased plant height, stem diameter, number of leaves and leaf area (Khalid et al., 2003). Mahmud et al. (2003) from Faisalabad (Pakistan) observed that application of 100 kg P_2O_5 ha^{-1} significantly increased plant height, stem diameter and helps to produce broader leaf. Similarly, Roy and Khandaker (2010) in Bangladesh observed that the application of phosphorus fertilizer 80 kg ha^{-1} has significantly increased the plant height of sorghum up to 60 DAS. A positive effect of phosphorus with respect to plant height observed under 120 kg P_2O_5 ha^{-1} up to 60 days in 1st cutting and subsequently in 2nd and 3rd cuttings (Roy et al., 2015). The increased in lead area index (LAI) was recorded with an increasing the levels of recommended dose of phosphorus application up to 25% (Satpal et al., 2015). Experiment conducted by (Hakeem et al., 2018) in two locations (Minjibir and BUK) of Sudan savanna zone (Nigeria) and reported that the plant height increased with inclining level of phosphorus up to 45 kg ha^{-1}, beyond this it leads to negative effect on height. The tallest plants (216.5 cm) recorded with the application of 45 kg P ha^{-1}. Growth attributes with respect to plant height, stem diameter, Leaf Area Index and number of basal node tillers gradually increased with increase of phosphorus levels from 0, 11.5, 23.0 and 34.5 kg P_2O_5 ha^{-1} (Biya, 2018). Plant height increased with increasing P application due to the involvement in cell division and root growth.

7. IMPACT OF PHOSPHORUS FERTILIZATION ON YIELD AND YIELD ATTRIBUTES

Soil application of 60 kg P_2O_5 ha^{-1} produced significant higher green fodder yield over control (0 kg P_2O_5 ha^{-1}) and 30 kg P_2O_5 ha^{-1} (Abichandani et al., 1971, Sumeria et al., 2002). Green and dry fodder yield increased significantly with the application of 40 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} (Chotiya and Singh, 2005, Vashishatha et al., 1997). Similarly, experiment conducted at Jhansi by Sharma and Agrawal (2003) reported application of NPK (90:40:30) kg ha^{-1} under semi-arid conditions significantly increased green fodder (62.1 t ha^{-1}), dry matter (12.74 t ha^{-1}) and crude protein yield (0.8 t ha^{-1}) in forage sorghum over control, 60:30:20 and 30:20:10 NPK, respectively. At, Bangladesh, Roy and Khandaker (2010) found that the significant effect in green matter yield was observed at 80 kg TSP ha^{-1} in 2nd and 3rd cutting over control, 40 kg TSP ha^{-1} and 120 kg TSP ha^{-1}. Results of various studies conducted at different places indicated that application of 120 kg P_2O_5 ha^{-1} is sufficient and gave significant higher green fodder yield and dry matter yield in all the three cuts over the 0, 40 and 80 kg P_2O_5 ha^{-1} (Roy and Tudu, 2013, Roy et al., 2015). In another study Satpal et al. (2015) at Hisar (Haryana) reported application of 125% of RDF (100 kg N and 50 kg P_2O_5 ha^{-1}) yields significantly higher green fodder (42.84 t ha^{-1} dry matter yield (11.32 t ha^{-1}) and crude protein yield (1.15 t ha^{-1}) than other treatments except application of RDF (80 kg N and 40 kg P_2O_5 ha^{-1}). Similarly, at Nigeria, Hakeem et al. (2018) reported that the dry fodder yield increased with increase in P fertilizer levels from zero to 45 kg ha^{-1}. In Pakistan, experiment conducted by Rashid and Iqbal (2011) observed that the maximum green fodder yield of 32.16 t ha^{-1} and dry matter yield of 13.89 t ha^{-1} obtained from P applied with 25 kg ha^{-1} and 43 kg ha^{-1}.

8. IMPACT OF PHOSPHORUS FERTILIZATION ON QUALITY TRAITS

Phosphorus application did not show significant effect on ADF and NDF contents in fodder. However, the slight decrease in the quality of these traits and increase in soluble carbohydrates in fodder with the P fertilization and showed quality improvement (Reid and Jung 1965; Chand et al., 1992, Pholsen and Sukseri, 2007). Crude protein content gradually increased up to 30 kg P_2O_5 ha^{-1} further increase in phosphorus did not show any further effect (Medina Lucio et al., 1984). Crude protein content in sorghum fodder was increased with P application as reported by various workers (Mengel and Kirkby, 2001, Polat et al., 2007, Afzal et al., 2012). They also revealed that fodder sorghum cv.J.69 markedly increased the crude fibre (CF) content with the application of 50 and 100 kg P_2O_5 ha^{-1} (Khaddar et al., 1985). The increase in crude fiber contents increased the dry matter accumulation with P application (Chand et al., 1992, Ayub et al., 2002). However, contrary Roy et al. (2015) from Nadia, West Bengal reported that crude fibre (CF) content decreased significantly with the increased dose of phosphorus in all the three cuttings of sorghum crop. Rashid and Iqbal (2011) from Pakistan reported that the maximum crude protein, crude fiber and ash contents were 9.25, 30.12 and 13.45%, respectively in sorghum fodder due to application of phosphorus with 43 kg P ha^{-1}. The higher crude protein (CP) content was recorded at 120 kg P_2O_5 ha^{-1} while ether extract (EE) and nitrogen free extract (NFE) were increased significantly with the application of phosphorus in all the three cuts over the 0, 40 and 80 kg P_2O_5 ha^{-1} (Roy and Tudu, 2013). Study made by Abou-Amer and Kewan (2014) at Maryout (Egypt) reported that maximum crude protein values were 12.38, 11.52 and 10.45% with application of 40 kg P_2O_5 ha^{-1} and followed by 12.17, 11.52 and 10.12% over 30 kg P_2O_5 ha^{-1}, in the first, second and third cutting, respectively.

9. EFFECT OF MICRONUTRIENTS

Micronutrient deficiencies have been emerging as a major problem in many intensively cultivated soils of India and have recognized as a critical yield–limiting factor in forage crops and quality deterioration. Micronutrients, also known as trace minerals, which chiefly include boron (B), molybdenum (Mo), copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) are required in extremely small quantities by crops and livestock. In many parts of India, zinc now stands third in importance next to nitrogen and phosphorus (Takkar and Randhawa, 1980). Zinc plays a vital role in oxidation processes in cells and helps in transformation of carbohydrates and regulation of sugar in plant (Swaminathan and Kannan, 2001). It influences N metabolism and uptake, protein quality, photosynthesis, chlorophyll synthesis, carbon anhydrase activity, resistance to abiotic and biotic stresses and protection against oxidative damage (Cakmak, 2002, Pandey et al., 2002). Role of iron is its catalytic function in biological oxidation and reduction in plants like oxidative photophosphorylation during cell respiration. Iron is a constituent of a large number of metabolically active compounds like cytochromes, heme and nonheme enzymes and other functional metalloproteins (Rathod et al., 2005). The role of boron is also very important role in plant, including RNA and cytokine in production and transfer, meristem sugar and hydrocarbon metabolism and their transfer, building of pollen and formation of seed (Murthy et al., 2006).

10. IMPACT OF MICRONUTRIENTS ON GROWTH AND GROWTH ATTRIBUTES

Increase in different growth parameters such as plant height, leaves/plant and tillers plant^{-1} with Fe addition can be attributed to the fact that Fe has a structural and physiological role in different processes like chlorophyll formation, thylakoid synthesis, chloroplast development, energy transfer and photosynthesis, so having essential role in enhancing plant growth and development (Cakmak, 2002, Singh et al., 2011, Ali et al., 2014). In Iran, Soleymani and Shahrajabian (2012) suggested that foliar application of Zn+Fe+Mn in combination caused the highest plant height, LAI, numbers of leaves per plant and dry leaf weight/dry stem weight in forage sorghum. In another study, Rana et al. (2013) at Hisar (Haryana) observed that the maximum plant height (266.3 in 2009 and 257.0 in 2010) and number of tillers (23.3 and 20.6 in 2009 and 2010, respectively) were recorded in the treatment RDF+0.5% $ZnSO_4$ foliar application at 35 and 45 DAS. A pot experiment conducted by Alkhamisi et al. (2017) at Rumais, Oman and reported that application of Boron concentrations 5 mg l^{-1} caused maximum plant height (144.46 cm) as compared to 0, 1, 2.5, 7.5 and 10 mg B l^{-1}. At Gujarat, Chaudhari et al. (2017) at Anand, Gujarat reported that increasing the level of cobalt (Co) from 0 to 20 mg kg^{-1} soil in pot significantly increased plant height of sorghum over 0, 40 and 80 mg Co kg^{-1} soil, it was *at par* with 10 mg kg^{-1} Co level. The study carried out by Prajapati and Kewalanand (2019) at Pantnagar, Uttarakhand reported that growth attributes like plant height, stem diameter and Leaf: Stem ratio were highest due to RDF+$ZnSO_4$ 15 kg ha^{-1}+$FeS0_4$ 15 kg ha^{-1} as soil application.

11. IMPACT OF MICRONUTRIENTS ON YIELD AND YIELD ATTRIBUTES

Application of Fe and Zn individually or in combination via soil and plant registered significant higher fodder yield over control. Z, the foliar application of $ZnSO_4$ and $FeSO_4$ with RDF at different growth stages did not produce any significant effect on yield as compared to recommended dose of fertilizer alone during both the years (Mali and Doshora, 2003). In another study, Tripathi et al. (2007) at Jhansi reported that application of sulphur (40 kg ha^{-1}), Zn (20 kg ha^{-1}) and Mn (10 kg ha^{-1}) along with recommended NPK to sorghum gave significantly higher dry fodder yield by 16.5% over NPK alone (32.52 t ha^{-1} green and 8.48 t ha^{-1} dry fodder). Similarly, Tiwana and Chaudhary (2009) at Ludhiana during 2007 and 2008 also found that application of 100 % RDF+25 kg Zn ha^{-1} recorded highest green fodder. An improvement in yield by the influence of foliar Zn fertilization due to its profound effect on plant height and dry matter production (Kaushik et al., 2010, Meena et al., 2010). Experiment was conducted by Soleymani and Shahrajabian (2012) at Esfahan, Iran reported that foliar application of Zn+Fe+Mn in combination caused significantly increase in fresh fodder yield, dry leaf yield and dry stem yield by sorghum over control (without using any fertilizer), Fe (12%), Zn (10%), Mn (5%), Fe+Zn, Fe+Mn and Zn+Mn, respectively. Zinc has vital role in photosynthesis and metabolic process augments the production of photosynthates and their translocation to different plant parts, which ultimately enhanced the concentration of zinc in green fodder. Increase in uptake of zinc is combined effect of substantial increase in concentration and higher dry fodder yield in response of increasing levels of zinc (Meena et al., 2013). Rana et al. (2013) emphasized that foliar application of 0.5% $ZnSO_4$ at 35 and 45 DAS produced maximum green fodder yield of 593.3 q ha^{-1} and 488.3 q ha^{-1} during 2009 and 2010 as well as dry matter yield of 171.6 and 141.6 q ha^{-1} respectively, followed by foliar application of 0.5% $ZnSO_4$ at 45 DAS only. Similarly, Ahmad et al. (2018) noted the improvement in green fodder yield up to 7.15% (2014) and 7.41% (2015) through application of 10 kg Zn ha^{-1} compare to control (Zn_0). Research findings of Prajapati and Kewalanand (2019) reported that RDF+$ZnSO_4$ 15 kg ha^{-1} +$FeS0_4$ 15 kg ha^{-1} as soil application significantly gave the highest green fodder yield of 613.36 and 624.63 q ha^{-1} and dry fodder yield of 170.39 and 177.21 q ha^{-1} as well as crude protein yield of 16.65 and 17.44 q ha^{-1} during 2012 and 2013, respectively. The increase in crude protein yield up to 75% in sorghum fodder with two foliar spray of 0.5% $FeSO_4$ at 35 and 45 DAS over control. Alkhamisi et al. (2017) conducted a pot experiment at Oman and found that application of Boron @ 5 mg l^{-1} recorded maximum green and dry forage yields. In another study, Choudhary et al. (2017) conducted at Udaipur, Rajasthan found that application of Fe+Zn+B along with RDF accumulate maximum dry matter of 14.58 t ha^{-1}. Another study conducted at Anand, Gujarat revealed that application of cobalt @ 20 mg kg^{-1} soil significantly increased green forage yield of sorghum.

12. IMPACT OF MICRONUTRIENTS ON QUALITY TRAITS

Jin et al. (2006) reported that proper foliar fertilization of Fe at different stages of crop activated nitrate in leaf, which is responsible for protein formation in plants. Similarly, Kaushik et al. (2010) suggested that application of RDF in combination with Zn and Fe significantly increased content by crude protein and crude fiber over RDF alone. Application of Zn resulted in higher protein synthesis and lowered the soluble carbohydrates which could be responsible for lower content of Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) in fodder (Almodares et al., 2009). Similarly, Sharifi and Taghizadeh (2009) found that Zn application increased both N content and its uptake due to the synergistic relation between N and Zn. Rana et al. (2013) reported that the highest crude protein content was recorded with RDF+0.5% $FeS0_4$ foliar spray at 45 DAS as well as two foliar spray at 35 and 45 DAS. Number of studies has shown that foliar sprays of iron increased the IVDMD and DDM in sorghum fodder. Application of RDF in combination with Zn and Fe significantly increased content of crude protein and crude fiber (Kaushik et al., 2010). While working at Parbhani, Maharashtra, Pawar et al. (2015) revealed that zinc sulphate and ferrous sulphate micronutrient through soil and foliar application along with recommended dose of NPK fertilizers improved the quality parameters of *kharif* sorghum fodder like crude protein, crude fiber, crude fat, starch, soluble sugar, ash content, calorific value of crude protein, dietary fiber, organic matter, ether extract and nitrogen free extract. Experiment conducted by, Prajapati and Kewalanand (2019) at Pantnagar, Uttarakhand reported that RDF+$ZnSO_4$ and $FeS0_4$ @ 15 kg ha^{-1} each as soil application enhanced dry matter content of 27.78% and crude protein content of 9.79%.

13. CONCLUSION

It is concluded that judicious use of nitrogen and phosphorus improve the performance of fodder sorghum. Combined application of micronutrients especially zinc (Zn), iron (Fe) and manganese (Mn) along with recommended dose of N and P has significant role to boost up plant growth, green fodder, dry fodder, crude protein and digestible dry matter yields of sorghum fodder.

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