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A review on the response of nitrogen management on yield, yield attributes & quality of Forage Sorghum (*Sorghum bicolor* L.)

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Abstract
Effect of various nitrogen management on yield, yield attributes & quality of forage Sorghum (*Sorghum bicolor* L.) revealed that sowing of sorghum with increasing levels of seed rate recorded significantly higher dry matter and green forage yield owing to significant increase of growth attributes over the lower levels of seed rate. The quality parameters *viz*., nitrogen and crude protein content significantly increased while ADF and NDF significantly decrease with decrease in levels of seed rate. The higher gross return, net return and benefit cost ratio was observed when crop was sown with higher seed rate than lower doses of seed rate similarly increase in nitrogen levels recorded significantly higher dry matter, green forage and crude protein yield. Regarding the quality parameters *viz*., nitrogen content in plant, crude protein content, cell content and ash content increased while ADF and NDF content of sorghum decrease with increasing levels nitrogen at all cuttings during both the years of experiment.

Keywords: Sorghum, seed rates, nitrogen levels, cutting management

Introduction
Sorghum [*Sorghum bicolor* (L.)] also known as "Jowar" is the king of coarse cereals. It is also famously known as "Camel Crop" because of its ability to grown in arid soils & with stand prolonged draught. It is an important feed, food, fodder and ration for cattle, poultry and also for human needs. There is a great need to maintain regular well-balanced supply of more nutritious feed and fodder in the state. Fodders are one of the cheapest source of nutrients as they not only meet the requirement of bulk to be fed to the cattle, but also supply desired amount of protein, energy, minerals as well as vitamins to a large extent. The grains of sorghum have about 10-12% protein, 3% fat and 70% carbohydrate. Sorghum fodder contains more than 50% digestible nutrients which consist of 8% protein, 2.5% fat, 45% nitrogen-free-extract (NFE), 70% carbohydrates and minerals. Livestock is the backbone of agricultural economy and has immense significance to complement an agricultural livelihood. Uttar Pradesh despite having a large livestock population of 67.8 millions lags in milk productivity. Inadequate & poor-quality feed & fodder supplied to the milch animals is the main reason for lower milk productivity. There is an urgent need to boost the production of good quality fodder for improving the health of the vast livestock population of the state.

The main sorghum growing states in India are Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, Rajasthan & Gujarat. In that, Maharashtra ranks first in sorghum production area, but in case of productivity Andra Pradesh ranks first while Maharashtra ranks third in productivity. In Uttar Pradesh, Sorghum occupies around 0.25 million ha area with 0.337 million tonnes production & productivity of 1348 kg/ha comprising of grain, forage and other sorghums. Nitrogen increases plant height which results in increased number of leaves per plant & also increases stem diameter (Midha *et al*., 2014) [46].

Effect of Nitrogen Management

Effect on Growth and Yield

Tomar and Agarwal (1993) conducted experiment on effect of bio-fertilizer (*Azosprillium*) as an alternative source of nitrogen for enhancing fodder production. They found that the green fodder yield of sorghum crop increased with increasing levels of nitrogen up to the maximum dose of 120 kg N ha^{-1}.

Tripathi and Bhan (1995) reported from central Uttar Pradesh and found that application of 60 kg N ha^{-1} in two split i.e. half at planting in furrows 2-3 cm below the seed and remaining half side dressed about 5 weeks after planting significantly increased the sorghum yield and its attributes. Side dress application of nitrogen fertilizer at eight - leaf growth stage is feasible and would be beneficial for sorghum.

Pawar *et al.* (1996) [59] revealed that combined effect of *Azotobacter* and *Azospirillium* with nitrogen on yield of sorghum (CSH-9) from College of Agriculture Pune, application of 120 kg N ha^{-1} along with dual inoculation gave maximum grain yield (48.95 q ha^{-1}) and were at par with that of 90 kg N ha^{-1} with inoculation of bio-fertilizers and 120 kg N ha^{-1} without inoculation of bio-fertilizers.

Saheb *et al.* (1997) conducted a field experiment in *kharif* at Karnal, Harayana, and they found significant increase in the total dry matter and its all components were obtained with an increase in the level of nitrogen from 0 to150 kg ha^{-1}.

Vashishatha and Dwivedi (1997) conducted experiment on effect of nitrogen and phosphorus on M P Chari sorghum and they found that application of nitrogen up to 150 kg ha^{-1} increased the green forage and dry matter under first and second cuts, but significant response was recorded only up to 100 kg N ha^{-1}.

Patil and Deshpande (1999) [57] studied the effect of nutrient management in *rabi* sorghum under dry land conditions and reported that increased grain yield (12.27 q ha^{-1}) with FYM + Urea combination (25 kg N FYM + 25 kg N Urea ha^{-1}) which was higher than that of chemical fertilizer along (50 kg N Urea.)

Dadheech *et al.* (2000) [22] conducted a field experiment in *kharif* 1991-92 in Udaipur, Rajasthan, India. They reported that green and dry fodder yields, increased with increasing N rate up to 80 kg ha^{-1}. Among the cultivars, SU-1 had significantly higher green and dry fodder yields.

Gadhethariya *et al*. (2000) [26] observed the effect of nitrogen (N) and bio-fertilizers on the growth and yield of a multi-cut cultivar of forage sorghum (GFSH-1) during the *kharif* season of 1995-96 in Gujarat, India. They reported that N application produced significant effect on the yield and yield components. Increased response was observed up to the highest N level. Every increment in N produced significantly higher forage yield over the preceding N level. Significantly higher green (607 and 261 q ha^{-1}) and dry forage yields (318 and 141 q ha^{-1}) were produced when the forage crop was treated with 120 and 60 kg N ha^{-1} during the first and second cut, respectively over the control.

Kumar *et al*. (2001) [38] conducted a field investigation at Rajasthan Agriculture University, Rajasthan to study the interaction affect between nitrogen levels and cutting management on yield and quality of different cultivars of oat and they revealed that the yield of green forage (411.6 q ha^{-1}) and dry matter (79.1 q ha^{-1}) of oat variety Kent were higher in single cut than two cut system (338 q ha^{-1} and 62.7 q ha^{-1}) respectively with increased level of nitrogen up to 120 kg N ha^{-1}.

Bhilare *et al.* (2002a) [15] conducted an experiment on a clayey soil during *kharif* season at Rahuri (Maharashtra) and reported an increase in dry fodder yield by applying 120 kg ha^{-1} in three equal spits i.e., 1/3rd at basal + 1/3rd at 30 DAS +1/3rd after first cut.

Rathod *et al.* (2002) [63] conducted field trial on a black soil Dhari (Gujarat) during the *kharif* season and reported that the green fodder yield and dry fodder yield of forage sorghum increased with increasing level of nitrogen up to 120 kg ha^{-1}.

Agarwal *et al*. (2005) [1] observed statistically higher leaf to stem ratio with increasing level of nitrogen up to 150 kg ha^{-1} on a sandy loam soil of Jabalpur (MP) during *kharif* season.

Singh *et al.* (2005) revealed from the trial conducted at Faizabad (UP) during *kharif* season and reported that each incremental dose of nitrogen up to 100 kg ha^{-1} significantly increased the multicut sorghum plant height.

Shivadhar *et al.* (2005) [40] reported from Jhansi (UP) significant increase in number of green leaves by increasing nitrogen level from 40 to 80 kg ha^{-1} on clay loam soil.

Bhilare and Joshi (2008) [14] conducted a field experiment on response of oat (*Avena sativa* L.) cultivars UPO - 212 to nitrogen levels at Instructional Dairy Farm, G B. Pant University of Agriculture and Technology, Pantnagar and revealed that the application of 120 kg N ha^{-1} significantly produced green forage yield (428.9 q ha^{-1}) and dry matter yield (81.1q ha^{-1}) while 160 kg N ha^{-1} produced green forage yield (445.3 q ha^{-1}) and dry matter yield (83.7 q ha^{-1}) which was at par to each other in case of variety UPO - 212.

Pathan and Bhilare (2009a) [54] observed from a field experiment conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri to study the response of nitrogen levels to single cut oat genotypes during *rabi* 2006-07 and they observed that increasing nitrogen levels up to 120 N kg ha^{-1} significantly increased the higher plant height (129.70 cm) in variety RO-19 and the higher plant population (94.17 m^{2}) in variety UPO-04-01.

Muhammad *et al.* (2011) [47] conducted an experiment on effect of different nitrogen levels and seed rates on fodder yield and quality of maize (*Zea mays* L.) and observed that increase in nitrogen dose significantly increased the stem diameter, leaf area plant^{-1}, fresh weight of plant, dry matter yield of forage maize.

Roshan *et al.* (2012) [64] studied the interaction effect between cultivars and nitrogen levels under agro climatic conditions of Kymore plateau zone, Madhya Pradesh and reported that increasing nitrogen levels up to 120 N kg ha^{-1} significantly increased the plant height (144.3 cm), number of tillers (410.3 m^{-2}) and LAI (6.38 at 50% flowering) in Kent as compared to OS - 6 in case of plant height (144.2 cm), number of tillers (404.4 m^{-2}) and LAI (5.54 at 50% flowering).

Singh *et al*. (2012) conducted a field experiment at Udaipur (Rajasthan) to ascertain the effect of nitrogen and seed rate on growth and yield of summer fodder sorghum and concluded that application of 80 kg N ha^{-1} significantly higher plant height, stem diameter, dry matter production and number of functional leaves plant^{-1} at different crop growth periods. Stem diameter showed significant and consistent increase, whereas leaf: stem ratio recorded significant and consistent decrease with increase nitrogen application.

Jha *et al.* (2012) [33] reported from trial conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP) during *rabi* season of 2007-08 with the objective to determine the relative performance of new single cut oat genotypes in combination of nitrogen levels *viz.*, 0, 40, 80 and 120 kg N ha^{-1}and reported that, the variety JO-03-91 with 120 kg N ha^{-1} proved significantly superiors in producing maximum green fodder (503.9 ha^{-1}) and dry matter yield (121.1 q ha^{-1}).

Bhoya *et al*. (2013) [16] conducted field experiment on loamy sand soil of the Agronomy Instructional Farm, Sardar

krushinagar, Dantiwada Agricultural University, (Gujarat) to study effect of nitrogen on yield and quality of fodder sorghum cultivars during summer season of 2011 and recorded that application of 120 kg N ha^{-1} significantly increased green forage (262.44 q ha^{-1}) as well as dry matter yields (120.28 ha^{-1}).

Jehangir *et al.* (2013) [32] carried out field experiment during winter seasons of 2009-10 and 2011-12 at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar and recorded that application of 150 kg N + 30.8 kg P2O5 + 33.3 kg K2O ha^{-1} to fodder oat gives higher green fodder (36.2 t ha^{-1}) and dry fodder yield (10.2 t ha^{-1}).

Rana *et al*. (2013) [62] from Hisar (Haryana) reported significant increase in plant height, number of tillers per meter row length of sorghum genotypes were significantly influenced by different fertility levels. The maximum plant height, number of tillers was recorded at 150 per cent of recommended dose of fertilizer which was significantly higher than lower doses of fertilizers.

Shahin *et al.* (2013) revealed that significant increases were appeared in plant height (cm), number of tillers m^{-2}, number of leaves m^{-2} and leaf area index of pearl millet as nitrogen fertilization rates increased.

Choudhary *et al.* (2014) [20] conducted field trial during rainy season of 2011 and 2012 at Indian Grassland and Fodder Research Institute, Jhansi, U.P. and they observed that application of 125% RDF recorded significantly higher green fodder equivalent yield (53.75 t ha^{-1}) and crude protein yield (696 kg ha^{-1}) being 9.3 and 17.4% higher over 100% RDF.

Eajaz *et al*. (2014) [25] was carried out field study during rainy season of 2012 at Karnal, Haryana to evaluate the effect of four levels of nitrogen (0, 60,120 and 180 kg ha^{-1}) on dual purpose baby corn and they observed that most of the growth and yield attributes were significantly improved by nitrogen application up to 120 kg N ha^{-1}. However, green (32.3 t ha^{-1}) as well as dry fodder yield (6.66 t ha^{-1}) increased significantly with increase in level of nitrogen application up to 180 kg $ha^{-1.}$

Midha *et al.* (2014) [46] from Hisar (Haryana) reported significant increase in plant height, number of tillers per meter row length, green fodder and dry matter yield of sweet sorghum genotypes were significantly influenced by different fertility levels. The maximum plant height, number of tillers, green fodder and dry matter yield were recorded at 120 kg N ha^{-1}, which were significantly higher than lower dose i.e. 80 kg N ha^{-1}.

Patil *et al.* (2014) [58] conducted an experiment during *rabi* season of 2010-11 at JAU, Junagarh (Gujarat) to find the effect of nitrogen and phosphorus on yield, quality and economics of forage maize and reported that application of 100 kg N ha^{-1} and phosphorus 50 kg P2O5 ha^{-1} recorded significantly the highest plant height, number of leaves $plant^{-1}$, number of internodes $plant^{-1}$, stem thickness, length of internodes, leaf area index, chlorophyll content.

Somashekar *et al*. (2015) carried out field study at Zonal Agricultural Research Station, Visweswaraiah Canal Farm, Mandya (Karnataka) during *kharif* seasons of 2011 and 2012 in fodder sorghum and they reported that application of 30 kg ha^{-1} nitrogen recorded significantly higher growth parameters like plant height (153.34 and 149.45) respectively, number of tillers m^{-1} row length (77.51 and 72.28) respectively, Leaf : stem ratio (0.26 and 0.25) respectively.

Kendra *et al.* (2016) [36] conducted field trial at Udaipur (Rajasthan) reported that the fodder sorghum fertilized with 125 per cent RDF recorded significantly highest plant height, stem girth, leaves $plant^{-1}$, leaf : stem ratio and dry matter accumulation over application of 100, 75 and 50 per cent RDF.

Kumawat *et al.* (2016) [41] conducted field experiment for three consecutive years on fodder pearl millet during *kharif* season of 2012, 2013 and 2014 at Bikaner (Rajsthan) and they observed that higher plant height (165.67 cm), tillers m^{-1} row length (30.89) and leaf : stem ratio (2.31) were recorded with 150% recommended dose of nitrogen.

Nirmal *et al*. (2016) [50] conducted a field experiment at the research area of Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S) during *kharif* season 2015 and reported that forage sorghum received 125% N of RDF ha^{-1} recorded significantly maximum forage yield (60.6 t ha^{-1}) followed by application of 100% N of RDF ha^{-1} (56.5 t ha^{-1})

Kar *et al*. (2017) [34] carried out field experiment at Karnal, Haryana during *kharif* season of 2014 - 15 to estimate green fodder yield, dry fodder yield and N uptake in fodder maize, fodder sorghum and sugar graze. Among the fertilizer sources, 100% N through inorganic form recorded highest green fodder (51.10 t ha^{-1}), N uptake (230 kg ha^{-1}) and crude protein (10.2%).

Effect on Quality

Dadheech *et al.* (2000) [22] conducted a field experiment in *kharif* 1991-92 in Udaipur, Rajasthan, India. They reported that SU-1 had significantly higher contents of crude protein, crude fat and NFE, accumulation of crude protein, crude fat, mineral matter and NFE, metabolizable energy.

Gadhethariya *et al*. (2000) [26] observed the effect of nitrogen (N) and bio-fertilizers on the quality parameters of a multi-cut cultivar of forage sorghum (GFSH -1) during the *kharif* season of 1995-96 in Gujarat, India. They reported that N application produced significant effect on quality parameters of forage. Increased response was observed up to the highest N level.

Ayub *et al*. (2001) [11] reported from Faisalabad, Pakistan similar performance 120 and 180 kg N ha^{-1} increasing of crude protein yield in sorghum.

Singh *et al.* (2005) conducted an experiment during the rainy seasons of 2001, 2002 and 2003 at Faizabad, Uttar Pradesh, India, to study the effect of nitrogen and bio-fertilizer inoculation on the production potential and protein content of forage sorghum. They reported that the maximum green forage and dry matter yields and crude protein content were obtained at 100 kg N ha^{-1}, which were significantly higher than the other treatment.

Verma *et al.* (2005) reported from an experiment conducted on a silty clay loam soil during rainy season a Pantnagar (Uttarakhand) and reported increased crude protein yield with the increase in N level upto 120 kg ha^{-1}.

Bishanoi *et al.* (2006) [17] conducted trial and reported that the crude fibre per cent of forage sorghum increased with increased levels of nitrogen from 80 to 120 kg ha^{-1} during *kharif* season at Udaipur (Rajasthan).

Almodares *et al.* (2009) [6] reported that application of 200 kg urea ha^{-1} significantly increased the highest protein content (8%), lowest soluble carbohydrates (12.80%) and fibre contents (31.90%). In fodders as the nitrogen fertilizer increased, crude protein present increased while crude fibre present decreased which could increase palatability and digestibility of the sweet sorghum.

Marco *et al.* (2009) [44] found that the stage of crop growth is the most important factor influencing the quality and quantity of forage produced. Maximum green fodder with highest nutritive value is obtained at 50 per cent flowering stage. Advancing harvesting time lowers leaf: stem ratio and increases lignifications of forage. Crude protein concentrations, digestibility and intake would be significantly reduced as the

forage matured. Sweet sorghum with its high palatability for the animal can be used as forage.

Ahmad *et al.* (2011) [3] conducted a field experiment at Faislabad (Pakistan) observed that the maximum crude protein (10.76%), crude fibre (37.00%) and total ash of 15.14% were produced in inorganic sources (N: P2O5 150:60 kg ha^{-1}).

Muhammad *et al.* (2011) [47] revealed that maximum protein content (9.138%) were produced by application of 150 kg N ha^{-1} while the minimum (6.541%) were produced by the control. The protein content (9.13%) produced by 150 kg N ha^{-1} was 39.70% more than the protein content of control, 11.45 per cent more than 100 kg N ha^{-1} protein content 8.199 per cent and 17.34 per cent more than 50 kg N ha^{-1} protein content.

Luikham *et al.* (2012) [43] conducted a field experiment at College of Agriculture, Central Agricultural University, Imphal and reported that variety JHO - 822 recorded significantly highest crude protein yield 3.22 kg ha^{-1}) than other cultivars *viz.*, JHO - 851 (2.26 kg ha^{-1}), OF - 6 (2.63 kg ha^{-1}), and Kent (2.66 kg ha^{-1}) with increasing levels of nitrogen.

Pathan *et al.* (2012) [56] reported from trial conducted during 2009-10 and 2010-11 at Post Graduate Institute Farm, M.P.K.V., Rahuri and they observed that the application of 150% RDF registered significantly higher values of most of the forage quality parameters namely DMY, CPC, CFY, CFC, IVDMD, ash, cellulose and hemi-cellulose content as compared to rest of the fertilizer levels in Bajra × Napier hybrid.

Rana *et al.* (2013) [62] reported from trial conducted at Hisar, Harayana that the highest crude protein yield and digestible dry matter (DDM) were also recorded with 150 per cent RDF which were significantly higher than lower fertility levels.

Singh *et al.* (2014) conducted experiment during *kharif* 2009 at G. B. Pant Agricultural University, Pant Nagar. They observed that case of yield (fresh cane, sugar, juice and ethanol) quality parameters per cent of juice, sucrose, available sugar, juice purity, recorded significantly higher with application of 120 kg N ha^{-1} and at par with 180 kg N ha^{-1}, along with 10 kg seed ha^{-1}. However, brix was not affected significantly due to successive increase in nitrogen levels, while seed rate had no significant effect on all quality parameters.

Bochare (2015) [18] carried out research trial at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif* 2014. He was found that crude protein and crude fibre content as well as crude protein and crude fibre yield significantly noticed higher with the application of GRDF + 2% foliar spray of urea at 30 DAS in forage maize.

Ahmad *et al*. (2016) [4] observed that JS - 2002 had higher crude protein content (CP), crude protein yield (CPY), crude fibre (CF), crude fibre yield (CFY), ether extractable fats (EE), total ash content (TA) and organic matter (OM) whilst JS - 263 produced greater nitrogen free extract (NFE) than other cultivars. Increasing N rates (0 to 120 kg ha^{-1}) raised all above mention bio- chemical attributes but not NFE. Similarly, increased seed rate enhanced accumulation of CP, CF, EE, TA, CPY and CFY while caused reduction of OM and NFE. Genotypic variations may have influenced the accumulations of these traits however, differences were not significant. It was concluded that sorghum cultivar JS - 2002 seeded at 75 kg ha^{-1} with 120 kg N ha^{-1} application produced better quality forage under sub - tropical conditions.

Damame *et al.* (2017) [23] conducted a field experiment at Research Farm of AICRP on Forage Crops and Utilization, M.P.K.V., Rahuri, Maharashtra to access the effects of nitrogen levels on yield and quality of Bajra × Napier hybrid *cv.* Phule Jaywant and they reported that values of CP content, *in vitro* dry matter digestibility were the highest at 125% of RDN (8.53 and 69.93%, respectively).

Lagad *et al*., (2020) [42] carried a field trial at Post Graduate Instructional Farm, M.P.K.V. Rahuri, Maharashtra in summer 2018. The extent expression of quality parameters such as crude fibre content and IVDMD were non significantly influenced by different fertilizer treatments but crude protein yield (10.07 q ha^{-1}) and crude fibre yield (35.19 q ha^{-1}) were significantly higher under application of GRDF along 2% urea at 40 days after sowing.

Sutar *et al*., (2020) conducted an experiment at Post Graduate Instructional Farm, M.P.K.V. Rahuri, Maharashtra during summer 2017-18 to examine the effect of integrated nitrogen levels (GRDF, 150%, 125%,100%,75%) and cutting management. They reported that, dry matter content and crude protein content (8.58%) as well as IVDMD (62.83) were significantly highest due to application of 150% RDN (75% RDN- fertilizer + 25% - RDN through FYM).

Effect on Nutrient Uptake

Tomar and Agarwal (1993) concluded from the experiment conducted on effect of bio- fertilizer (*Azosprillium*) as an alternative source of nitrogen for enhancing fodder production. They found that the nutrient uptake of sorghum crop increased with increasing levels of nitrogen up to the maximum dose of 120 kg N ha^{-1}.

Tripathi and Bhan (1995) reported from afield investigation conducted at Central Uttarpradesh, application of 60 kg N ha^{-1} in two split i.e. half at planting in furrows 2-3 cm below seed and remaining half side dressed about 5 weeks after planting significantly increased the nitrogen uptake (235.56 kg ha^{-1}).

Pawar *et al.* (1996) [59] conducted a field experiment to study the combined effect of *Azotobacter* and *Azospirillium* with nitrogen on yield of sorghum (CSH-9) at College of Agriculture Pune and observed that the application of 120 kg N ha^{-1}along with dual inoculation showed higher uptake of Nitrogen and were at par with that of 90 kg N ha^{-1} with inoculation of bio-fertilizers and 120 kg N ha^{-1} without inoculation of bio-fertilizers.

Saheb *et al.* (1997) conducted a field experiment in *kharif* at Karnal, Harayana, reported that significant increased content of nitrogen and uptake with an increase in the level of nitrogen from 0 to150 kg ha^{-1}.

Gadhethariya *et al*. (2000) [26] reported the effect of nitrogen (N) and bio-fertilizers on the nutrient uptake of a multi-cut cultivar of forage sorghum (GFSH-1) during the *kharif* season of 1995-96 in Gujarat, India. They reported that N application produced significant effect on the nutrient uptake of forage. Increased response was observed up to the highest N level. Every increment in N produced significantly higher uptake over the preceding N level.

Kar *et al*. (2017) [34] carried out field experiment at Karnal, Haryana during *kharif* season of 2014 - 15 to estimate N uptake in fodder maize, fodder sorghum and sugar graze. Among the fertilizer sources, 100% N through inorganic form recorded highest N uptake (230 kg ha^{-1}).

Lagad *et al*., (2020) [42] carried a field trial at Post Graduate Instructional Farm, M.P.K.V. Rahuri, Maharashtra in summer 2018. The total uptake of nitrogen, phosphorus and potassium by forage sorghum was differed significantly due to different treatments of nutrient management. The application of treatment GRDF + 2% foliar spray of urea at 40 DAS (T2) recorded significantly higher nitrogen uptake (161.22 kg ha^{-1}).

Sutar *et al*., (2020) conducted an experiment at Post Graduate Instructional Farm, M.P.K.V. Rahuri, Maharashtra during

summer 2017-18 to examine the effect of integrated nitrogen levels (GRDF, 150%, 125%,100%,75%) and cutting management on forage pearl millet. Double cut recorded significantly higher total uptake of nitrogen, phosphorous and potassium uptake (314.80, 48.99 and 319.34 kg ha^{-1}, respectively) as compare to single cut this might be due to increased cutting interval and increase in fodder yield. The application of higher nitrogen, phosphorus and potassium respect to double cut recorded highest nitrate nitrogen in the plant but it was safe limit.

Effect on Economics

Karwasara and Dahiya (1997) [35] conducted trial on a sandy loam soil during *kharif* season at Hisar (Haryana) and noticed that application of 120 kg N ha^{-1} gave the maximum net return (₹ 5931 ha^{-1}) in fodder sorghum.

Akbari *et al.* (2000) [5] reported from trial conducted during 1991 to 1995 on a medium black clayey soil, at Targhadia, Gujarat and found that application of N @ 75 kg ha^{-1} also recorded the highest net return (12195 ha^{-1}) while N at 50 kg ha^{-1}had the highest net incremental cost : benefit ratio (1:1.182) over 5 years.

Dadheech *et al.* (2000) [22] observed from a field experiment conducted in *kharif* 1991- 92 at Udaipur, Rajasthan and reported that monetary returns and B : C ratio increased with increasing N rate up to 80 kg ha^{-1}.

Kumar *et al*. (2005) [40] reported that application of nitrogen @ 80 kg ha^{-1} maximum benefit cost ratio of 2.21 was obtained compared to other treatments at Jhansi (UP) during *kharif* season in fodder sorghum.

Singh *et al.* (2005) conducted an experiment during the rainy seasons of 2001, 2002 and 2003 at Faizabad, Uttar Pradesh, to study the 21 effect of nitrogen and bio-fertilizer inoculation on the production potential and protein content of forage sorghum reported that the highest gross monetary returns, net monetary returns and benefit : cost ratio was also obtained with 100 kg N ha^{-1}.

Jha *et al.* (2012) [33] observed from a field investigation conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP) and they reported that variety JO 03-91 having B : C ratio (5.03) being close to UPO 06-2 (4.68), UPO 06-1 (4.67) and Kent (3.96).

Luikham *et al.* (2012) [43] conducted field experiment at College of Agriculture, Central Agricultural University, Imphal revealed that variety JHO - 822 having the highest gross return (₹ 56232 ha^{-1}) net return (₹ 42854 ha^{-1}) and benefit cost ratio (1:3.20) than other three cultivars *viz.*, JHO - 851, OF - 6 and Kent.

Dubey *et al.* (2013) [24] revealed from a field experiment conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, (M.P) on effect of nitrogen levels on green fodder yield of oat (*Avena sativa* L.) cultivars during *rabi* season of 2006 - 07 and reported that variety OS-6 stood topped with respect of B: C ratio (2.27) and being close to Kent (2.23), JHO - 822 (2.06) and JHO - 851 (1.97).

Jehangir *et al.* (2013) [32] carried out field experiment during *rabi* seasons of 2009-10 and 2010-11 at S.K. University of Agricultural Sciences and Technology of Kashmir, Shalimar and they observed that application of 150:70:40 kg $N:P_2O_5:K_2O$ ha^{-1} to fodder oat markedly increased mean net returns (₹ 32856) and B:C (1.82) were registered with highest fertility level.

Somashekar *et al*. (2015) conducted an experiment consisting of 12 treatments and on the basis of the mean of four cuts data indicated that seed rate of 7.5 kg ha^{-1} with the application of 30 kg N ha^{-1} recorded significantly higher net returns (₹ 35018 and 31285 ha^{-1}) respectively and B : C ratio (2.40 and 2.20), respectively.

Satpal *et al.* (2016) reported that single-cut forage sorghum genotypes, SPH - 1752 proved significantly superior with respect tohighest net returns of ₹ 57516 ha^{-1} and B: C ratio of 2.40. Application of 125 per cent RDF also fetched highest net returns (₹ 50660 ha^{-1}) and B : C ratio (2.00) as compared to lower fertility levels.

Kumawat *et al*. (2016) [41] conducted field experiment for three consecutive years on fodder pearl millet during *kharif* season of 2012, 2013 and 2014 at Bikaner (Rajasthan) and they observed that higher net returns ₹ 74772 ha^{-1} and B : C ratio 4.22 were recorded with 150% recommended dose of nitrogen.

Choudary *et al*., (2018) [19] conducted field experiment during rabi season on fodder maize crop (Var. SHIATS Makka-2) at crop Research Farm Department of Agronomy, Nainital Agricultural Institute, SHUATS, Allahabad (U.P). The experiment comprised of three planting geometry and two N levels 90 kg N ha^{-1} and 120 kg N/ha respectively. The result revealed that 120 kg N ha^{-1} recorded higher gross return (89120 ha^{-1}), net returns (51351.61 ha^{-1}) and B:C ratio (2.36).

Sutar *et al*., (2020) carried an experiment at Post Graduate Instructional Farm, M.P.K.V. Rahuri, Maharashtra during summer 2017-18 to examine the effect of integrated nitrogen levels (GRDF, 150%, 125%, 100%, 75%) and cutting management on uptake and economics of forage pearl millet. The significantly higher gross monetary returns and net monetary returns was reported in double cut (158522 ha^{-1} and 108654ha^{-1}) as compare to single cut (75404 ha^{-1} and 40166 ha^{-1}) and B:C ratio (3.18).

Syuryawati *et al*., (2021) carried out research in Bontoramba, Jeneponto Regency, South Sulawesi in 2018 to determine the performance of sorghum farming with ratoon cultivation. Results showed that average yield of main crop was 5.92 t ha^{-1} and ratoon 5.83 t ha^{-1} with application of 300 kg urea + 100 kg SP36 + 100 kg KCl ha^{-1}.

Conclusion

After various studied we concluded that the response of nitrogen management to the yield and quality of forage sorghum bicolor is multifaceted, highlighting the critical role that nitrogen plays in optimizing both productivity and nutritional value. Effective nitrogen management strategies can significantly enhance forage yield, improve nutrient content, and promote better plant health, ultimately contributing to more efficient and sustainable forage production. However, the effectiveness of these strategies can vary based on soil conditions, climatic factors, and sorghum variety. Future research should focus on refining nitrogen application techniques and understanding the interactions between nitrogen management and other agronomic practices to maximize the benefits for forage sorghum cultivation. Continued advancements in this field are essential for achieving higher quality forage and improved economic returns for producers.

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