International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 1524-1528

Received: 28-01-2018
Accepted: 29-02-2018

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Nutrient management for higher fodder production of sorghum: A review

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Abstract
Adequate supply of quality forage is the basic necessity for sustainable livestock production. In India, supply of forage has always been a limiting factor for enhancing livestock production. The scope of increasing the area cultivated for forages is rather limited, because of mounting pressure and preferential need for food and commercial crops. Hence, fodder production has to be increased per unit area per unit time. Quality of forage is also very important to animal health and performance. Forage quality can be improved and the toxic principles can be alleviated by efficient nutrient management. Keeping these points in view, the literature pertaining to the fertilizer management in sorghum forage crops to obtain higher biomass production and good quality fodder has been reviewed.

Keywords: Nutrient management, higher fodder production, sorghum

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is predominantly grown for grain as wells as fodder in different parts of the country and is one of the widely grown forage crop with good nutritive value for animals. It is fast growing, adaptive to vast environmental conditions and provides palatable nutritious fodder to the animals. India has the largest livestock populace, which accounts for 17 per cent of the world's livestock population. However, livestock productivity is constrained by an acute shortage of feed and fodder. Sorghum is an important forage crop in India. As forage it is fast growing, palatable, nutritious and utilized as silage and hay besides fresh feeding. Sorghum crop is adaptive to vast environmental conditions and in India it provides green fodder to the animals for a considerable length of period i.e. from May to November (Suresh Kumar *et al*., 2013) [33].

Limited supply with poor quality of fodder is considered as major limiting factor for the livestock industry in India. The mainstay of animal health and their production depends on availability of fodder (Somashekar *et al.*, 2015) [30]. Importance of increasing the milk yield per animal through better health care and balanced feed and fodder supply has been relished by the farmers who have so far been growing fodder crops with traditional systems resulting in low productivity of fodder. The roots of sorghum synthesize hydrocyanic acid (HCN), a deadly poisonous material which is major anti-nutritional factor in sorghum fodder. The content of HCN varies with plant age and growth condition. Also the HCN potential is higher shortly after germination (Busk and Moller, 2002) [10]. During drought HCN concentration is observed to be increased. Every year casualties of cattle are observed due to grazing of sorghum fodder. The HCN content in sorghum varies with genotypes. The urbanization, ecological pressure and rising prices of basic inputs compel the breeders to introduce new varieties having ability to produce more with available resources. The use of varieties with higher productivity potential and ideal nutritional values, on one hand will make the livestock farming more profitable and on other hand ensure the availability of livestock products at low prices to the consumers (Ayub *et al*., 2012) [5].

Forage and feed – demand and supply scenario

The data/estimates of fodder production in the country vary widely. Fodder production and its utilization depend on the cropping pattern, climate, socioeconomic conditions and type of livestock. The cattle and buffaloes are normally fed on the fodder available from cultivated areas, supplemented to a small extent by harvested grasses and top feeds. Grazing and harvested grasses are the chief fodder source for equines, while camels usually subsist on top feeds, either browsed or lopped from shrubs and trees. The three major sources of fodder supply are crop residues, cultivated fodder and fodder from common property resources like forests, permanent pastures and grazing lands.

At present, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds. Supply and demand scenario of forage and roughage is presented in Table 1. The deficit and supply in crude protein (CP) and total digestible nutrients (TDN) are given in Table 2. The situation is further aggravated due to increasing growth of livestock particularly that of genetically upgraded animals. The available forages are poor in quality, being deficient in available energy, protein and minerals. To compensate for the low productivity of the livestock, farmers maintain a large herd of animals, which adds to the pressure on land and fodder resources. Due to ever-increasing population pressure of human beings, arable land is mainly used for food and cash crops, thus there is little chance of having good-quality arable land available for fodder production, unless milk production becomes remunerative to the farmer as compared to other crops. To meet the current level of livestock production and its annual growth in population, the deficit in all components of fodder, dry crop residues and feed has to be met from either increasing productivity, utilizing untapped feed resources, increasing land area (not possible due to human pressure for food crops) or through imports.

Table 1: Supply and demand scenario of forage and roughages (1995 - 2025) (in million tonnes)

Year	Supply		Demand		Deficit as % of demand (as actual)	
	Green	Dry	Green	Dry	Green	Dry
1995	379.3	421	947	526	568 (59.95)	105 (19.95)
2000	384.5	428	988	549	604 (61.10)	121 (21.93)
2005	389.9	443	1025	569	635 (61.96)	126 (22.08)
2010	395.2	451	1061	589	666 (62.76)	138 (23.46)
2015	400.6	466	1097	609	696 (63.50)	143 (23.56)
2020	405.9	473	1134	630	728 (64.21)	157 (24.81)
2025	411.3	488	1170	650	759 (64.87	162 (24.92)

Source: Based on X Five Year Plan Document, Government of India. Figures in parentheses indicate the deficit in percentage.

Table 2: Projected availability, requirements and deficit of CP and TDN (million tonnes) including CP and TDN from concentrates

Year	Requirement		Availability		Deficit (%)	
	CP	TDN	CP	TDN	CP	TDN
2000	44.49	321.29	30.81	242.42	30.75	24.55
2005	46.12	333.11	32.62	253.63	29.27	23.86
2010	47.76	344.93	34.18	262.02	28.44	24.04
2015	49.39	356.73	35.98	273.24	27.15	23.41
2020	51.04	368.61	37.50	281.23	26.52	23.70
2025	52.68	380.49	39.31	292.45	25.38	23.14

CP: Crude protein; TDN: total digestible nutrients.

The nutrient management practices in fodder sorghum have widely been described by various workers. At Udaipur, application of 80 kg N + 40 kg P_2O_5 ha^{-1} to forage sorghum significantly increased plant height, leaves $plant^{-1}$ and DMA at the all growth stages (AICSIP, 2005) [2]. At Jhansi (UP), Dhar *et al.* (2006) [11] recorded significant increase in dry matter of fodder sorghum with successive increase in nitrogen fertilizer rates up to 60 kg N ha^{-1}. A field experiment conducted during *kharif* season of 2003 and 2004 at Dharnia (Haryana) and result show that the application of 120 kg N ha^{-1} to forage sorghum gave maximum plant height, dry matter, stem girth and total number of leaves $plant^{-1}$ over rest of nitrogen levels (Karwasara and Kumar, 2006) [12]. At Tamil Nadu, application of 90 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} significantly increased plant height, number of tillers $plant^{-1}$, number of leaves $plant^{-1}$, leaf length, leaf width and leaf/stem ratio over lower fertility levels (Backiyavathy *et al.*, 2007) [6]. Application of 120 kg N + 40 kg P_2O_5 + 40 K_2O ha^{-1} gave significantly higher plant height (277.7 cm), stem girth (2.3 cm) and leaves $plant^{-1}$ (12.7) by 33.5, 28.9 and 23.3 per cent, respectively over control but was found at par with 80 kg N + 30 kg P_2O_5 + 30 K_2O ha^{-1} (Trivedi *et al.*, 2010) [34]. Application of 120 kg N + 40 kg P_2O_5 + 40 K_2O ha^{-1} to forage sorghum crop significantly improved plant height, LAI, leaves $plant^{-1}$ and dry matter accumulation $plant^{-1}$ by 12.1, 22.4, 11.5 and 22.8 per cent, respectively over 40 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} (Meena *et al.*, 2012) [17]. At Udaipur, showed that application of 80 kg N + 40 kg P_2O_5 ha^{-1} + 40 kg K_2O ha^{-1} significantly increased the plant height, leaves $plant^{-1}$ and DMA $plant^{-1}$ over rest of fertility levels (AICSIP, 2013) [4]. On the loamy sand soil of SK Nagar, low in organic carbon and available nitrogen, medium in available phosphorus and rich in available potassium, application of 120 kg N ha^{-1} to sorghum was found significantly superior to 80 kg and 40 kg N ha^{-1} as it enhanced the plant height, number of leaves per plant at harvest as well as leaf: stem ratio and length of internodes (Bhoya *et al*., 2014) [7]. Studies on the soil of Udaipur is clay loam in texture, slightly alkaline in reaction (pH 8.0), medium in available nitrogen (295.3 kg ha^{-1}) and phosphorus (16.6 kg ha^{-1}) while high in available potassium (270.7 kg ha^{-1}), the crop fertilized with100 per cent RDF produced higher green (74.93 t ha^{-1}) and dry fodder yield (21.55 t ha^{-1}) which was significantly higher than lower dose of fertilizer and control during 1st, 2nd and 3rd cuttings (Kumar and Chaplot, 2015) [13, 14, 15]. Application of 100 kg N + 40 kg P_2O_5 ha^{-1} to forage sorghum significantly increased plant height, dry matter accumulation $plant^{-1}$, leaves $plant^{-1}$, and LAI by 19.8, 8.8, 26.0 and 5.0 per cent, respectively over control (Buldak *et al.*, 2016) [9]. At Rahuri during the *kharif*, 2005 in the clay soil, low in available nitrogen, low in available phosphors, very high in potassium and slightly alkaline in reaction (pH 8.23), The application of 125% N level of RDF ha^{-1} significantly increased the growth attributes *viz.*, plant height, number of leaves $plant^{-1}$, dry matter $plant^{-1}$, number of internodes $plant^{-1}$ at harvest as compared to rest of the nitrogen levels and it was remained at par with the application of 100% N of RDF ha^{-1} (Nirmal *et al*., 2016) [20]. At Udaipur, soil was clay loam in texture, slightly alkaline in reaction (pH 8.0), medium in available nitrogen (290.5 kg ha^{-1}) and phosphorus (17.2 kg ha^{-1}), while high in available potassium (265.7 kg ha^{-1}), the result show that application of 125% RDF recorded significantly highest plant height (321.8 cm), stem girth (1.74 cm), leaves $plant^{-1}$ (13.1), leaf : stem ratio (27.4) and dry matter accumulation (126.6 g $plant^{-1}$) over application of 100, 75 and 50 per cent RDF (Singh *et al*., 2016). At Udaipur, application of 100% RDF *i.e.* 80 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} to forage sorghum significantly improved plant height, number of leaves $plant^{-1}$, leaf weight $plant^{-1}$, stem girth and dry matter accumulation $plant^{-1}$ by 5.5, 5.5, 6.2, 7.4, 6.4 and 18.2, 18.2, 18.9, 21.4, 11.5 per cent, respectively over application of 75 and 50% RDF (Yadav *et al*., 2016) [35, 36]. At Udaipur, soil was clay loam in texture, slightly alkaline in reaction (pH 8.20), low available nitrogen (248.1 kg ha^{-1}), medium in phosphorus (20.60 kg ha^{-1}) and organic carbon (0.61%) and high in available potassium (355.9 kg ha^{-1}). The crop fertilized with the application of 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} recorded significantly higher plant height and dry matter accumulation over 80 kg N

+ 40 kg P_2O_5 + 40 kg K_2O ha^{-1} and 60 kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1} (Meena *et al*., 2017).

At Udaipur, highest green and dry fodder yield of sorghum was obtained with the application of 80 kg N + 40 kg P_2O_5 ha^{-1} which was significantly higher over control and 40 kg N ha^{-1} by 16.9 and 48.3 per cent, respectively (Sumeriya and Singh, 2005) [32]. In Tamil Nadu, application of 90 kg N + 40 kg P_2O_5 +40 kg K_2O ha^{-1} produced maximum green (333.4 t ha^{-1}) and dry (64.0 t ha^{-1}) fodder yield (Backiyavathy *et al*., 2007) [6]. At Udaipur, application of 100% RDF (80 kg N + 40 kg P_2O_5 ha^{-1}) to forage sorghum crop significantly enhanced green fodder yield by 81.0, 38.6, 30.6 and 8.9 per cent and dry fodder yield by 81.0, 38.6, 30.6 and 8.9 per cent over control, 25, 50 and 75% RDF, respectively (Singh *et al.,* 2008). At Udaipur, application of 120 kg N + 40 kg P_2O_5 + 40 K_2O recorded maximum green (564.8 q ha^{-1}) and dry (175.3 q ha^{-1}) fodder yield of sorghum which were significantly higher by 38.0 and 49.4 per cent, respectively over control (Trivedi *et al*., 2010) [34]. In another study at Udaipur, it was noticed that application of 80 kg N + 40 kg P_2O_5 ha^{-1} gave highest green (409.8 q ha^{-1}) and dry (116.4 q ha^{-1}) fodder yield of sorghum which were significantly higher by 63.4 and 63.6 per cent, respectively over unfertilized control (Singh *et al.,* 2010). Further at Udaipur, maximum green and dry fodder yield was produced with the application of 150% RDF which was at par with 100% RDF, however both fertility levels significantly enhanced fodder yield over control and 50% RDF (AICSIP, 2011). Application of 80 kg N + 40 kg P_2O_5 ha^{-1} + 40 kg K_2O ha^{-1} gave highest green (667.9 q ha^{-1}) and dry (199.2 q ha^{-1}) fodder yield which were significantly higher over 50 and 25% RDF (AICSIP, 2013) [4]. At Dharwad where the soil was medium deep black clay having pH 7.0, low organic carbon(0.47%), low available nitrogen (203.7 kg ha^{-1}), medium available phosphorus (38.6 kg ha^{-1}) and high available potassium (320.3 kg ha^{-1}), result show that, the application of 300 kg N ha^{-1} to sorghum recorded significantly higher green fodder yield (179.63 t ha^{-1}) and dry matter yield (42.33 t ha^{-1}) compared to lower N levels (120, 180 and 240 kg N ha^{-1}) (Manjunatha *et al*., 2013) [16]. A field experiment conducted at Hisar in clay loam soil, low organic carbon and available Nitrogen and medium in available Phosphorus and potassium reviewed that application of 150% RDF resulted significantly higher green fodder (55.35, 22.36 and 11.82 percent) and dry matter yield (90.92, 36.04 and 17.78 percent) over control, 50% and 100% RDF respectively (Rana *et al.* 2013) [21]. On the clay loam, slightly alkaline soil ph (8.0) of Udaipur (Rajasthan), medium in available Potassium, application of 100% RDF (80 kg N + 40 kg P_2O_5 +40 kg K_2O) resulted in significantly increase in green and dry fodder yield of multi cut sorghum at first, second and third cutting stage. Application of 100% RDF gave 74.93 and 21.55 t ha^{-1} of green and dry fodder, respectively (Kumar and Chaplot, 2015) [13, 14, 15]. On the neutral soil ph (6.86) medium in available nitrogen, phosphorus and potassium, application of 30 kg N ha^{-1} recorded significantly higher green fodder yield (76.44 t ha^{-1}) as compared to 15 kg N ha^{-1} (65.19 t ha^{-1}) and was on par to 45 and 60 kg N kg ha^{-1} (77.27 and 80.26 t ha^{-1}). Likewise the dry fodder yield also increased significantly by raising rate of N application from 15 to 30 kg ha^{-1} compared to 15 kg N ha^{-1} (Somashekar *et al.,* 2015) [30]. At Palen (Telangana) having sandy clay loam soil, slightly alkaline in reaction ph (8.07), low in available N (213 kg ha^{-1}) and P (24 kg ha^{-1}) and high in available K (708 kg ha^{-1}), increase in fertility level from 50% RDF to 75% RDF and from 75% RDF to 100% RDF significantly increased sorghum plant height from 220 cm to 240 cm and from 240 cm to 253.4 cm (Sujathamma *et al.*, 2015) [31]. At Egypt, the result show that the highest yields of sugar and juice were 1.83 and 10.68 t fed^{-1} were obtained from the trilateral interaction among Brandes variety with 120 kg N fed^{-1} with 75 kg $Kfed^{-1}$ in the first season, respectively (Mekdad and El-Sherif, 2016) [19]. At Rahuri, the forage weight (g) $plant^{-1}$, forage production day^{-1} (kg ha^{-1}) and forage yield (t ha^{-1}) of forage sorghum were significantly increased linearly with increased nitrogen levels. Forage sorghum received with 125% N level of RDF ha^{-1} has significantly maximum forage weight (488 g $plant^{-1}$), forage production kg day^{-1} (887.3 kg) and forage yield t ha^{-1} (60.6 t ha^{-1}) followed by 100% N level of RDF ha^{-1} (460.0 g $plant^{-1}$ and 843.3 kg production day^{-1} and forage yield 56.5 t ha^{-1}),respectively (Nirmal *et al*., 2016) [20]. At Udaipur, forage sorghum fertilized with 100% RDF produced highest green (40.0 t ha^{-1}) and dry (12.7 t ha^{-1}) fodder yield representing significantly higher by 21.95, 22.11 per cent over 50% RDF and 6.98, 6.72 per cent over 75% RDF, respectively (Yadav *et al*., 2016) [35, 36]. At Udaipur, application of 100 kg N + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} recorded significantly higher green (41.08 t ha^{-1}) and dry (12.20 t ha^{-1}) fodder yield over lower fertility levels (Meena *et al*., 2017) [18].

At Udaipur, application of 80 kg N + 40 kg P_2O_5 ha^{-1} to forage sorghum significantly increased nitrogen, crude protein and crude fibre content in dry fodder (AICSIP, 2005) [2]. Rao *et al.,* (2007) reported that per cent crude protein content in dry fodder of sorghum was significantly improved with the application of 5 t FYM ha^{-1} + 50% RDF (4.9), 10 t FYM ha^{-1} + 50% RDF (4.7) and RDF (4.9) as compared to control (4.3). At Udaipur, application of 125% RDF (100 kg N + 50 kg P_2O_5 ha^{-1}) to sorghum significantly increased HCN content estimated at various growth stages *viz.*, 20, 40, 60 DAS and at harvest by 82.1, 80.7, 77.6 and 72.9 per cent over control and 97.7, 101.8, 96.2 and 88.0 per cent over 25% RDF kg ha^{-1}, respectively (Singh *et al*., 2008). Trivedi *et al*., (2010) [34] recorded highest crude protein uptake by sorghum crop with the application of 120 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} which was significantly superior by 94.3 per cent over control. Application of 80 kg N + 40 kg P_2O_5 ha^{-1} significantly increased crude protein, crude fibre, ether extract, mineral ash, NEE and TDN content by 109.5, 87.0, 81.9, 107.7, 44.7 and 62.6 per cent, respectively over control (Singh *et al.,* 2010). Studies on the soil of Hisar low in organic matter and available Nitrogen and medium available P_2O_5 and K_2O, enhancing the rate of nutrient application from control to 150% RDF did not affect the crude protein content of multi cut sorghum genotypes at 1st and 2nd cut, However the crude protein yield increased significantly from 6.66 and 4.52 q ha^{-1} to 11.80 q ha^{-1} by this increase fertility levels (Rana *et al*., 2013) [21]. At Cairo, Egypt, The results show that the impact of N and P treatments and their interactions on crude protein (%) were significantly higher than the control treatment, maximum crude fiber values were 12.38, 11.52 and 10.45 by applying N2P2 and followed by 12.17, 11.52 and 10.12 values by N2P1, in the first, second and third cutting, respectively (Abou-Amer and Kewan, 2014). In Pakistan, in a multi location trial, fertilizing sorghum forage with 120 kg N ha^{-1} produced the highest HCN content (21.5 and 13.4 mg 100 g^{-1}) at booting and 50% heading stage, respectively, while the lowest HCN content of 17.8 and 11.0 mg $100g^{-1}$ was recorded in control treatment where no fertilizer was applied (Sher *et al.*, 2014). At Udaipur, the result show that the application of 100 per cent RDF recorded highest HCN content during 1st (78.0 ppm) and 2nd (79.2 ppm) cuts which was significantly higher over 50 per cent RDF and control but at par with 75 per cent RDF (Kumar and Chaplot, 2015) [13, 14, 15]. On the sandy loam soil of Hisar, increase in fertility level from 40 kg N + 20 kg P_2O_5 to 100 kg N + 50 kg P_2O_5 tended to increase the HCN content of forage sorghum plant from 15.10 μg^{-1} of fresh weight whereas crude protein content increase from 6.53 to 11.46 percent (Satpal *et al.* 2015) [23]. In a two year experiment at Pantnagar, the soil was slight silty clay loam in texture, dark grayish brown to dark grey in humus with weak fine to medium granular structure, the result show that the highest total crude protein yield (0.92 t ha^{-1}), digestible dry matter yield (6.6 t ha^{-1}), juice yield (9,910 kilo litre ha^{-1}), sugar yield (0.91 t ha^{-1}) and calculated ethanol yield (2,762 kilo litre ha^{-1}) was recorded with application of 75% recommended dose of N through inorganic sources + 25% through vermi-compost (Singh *et al.*, 2015). Application of 100% RDF to forage sorghum recorded significantly higher ether extract (1.8%) and mineral ash (7.3%) content over 50 and 75% RDF, while concentration of crude protein (6.4%) and crude fibre (32.1%) content were higher with the application of 75% RDF. Further increase in fertility level did not produce any significant variation. Highest TDN (57.3%) and NFE (54.4%) content were obtained under 50% RDF, while there were lowest under 100% RDF (Yadav *et al.*, 2016) [35, 36]. At Udaipur, Application of 125% RDF recorded significantly increased content and uptake of crude protein, crude fibre, mineral ash and ether extract over lower fertility levels. Increasing fertility levels caused significant reduction in nitrogen free extract and total digestible nutrient content in dry fodder, which were highest in 50% RDF but application of 125% RDF significantly increased uptake of nitrogen free extract and total digestible nutrient uptake by dry fodder (Singh *et al*., 2017) [18].

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