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NITROGEN UPTAKE ASSOCIATION WITH BIOMASS YIELD AND FODDER QUALITY ATTRIBUTES IN SORGHUM GENOTYPES

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SUMMARY

The efficiency towards nitrogen uptake and its utilization may vary in different sorghum genotypes due to inherited biological nitrification inhibition potential. In this study, four sorghum single cut genotypes (SPH 1890, SPH 1891, CSV 30F and CSV 32F) were grown with three fertility levels (75% RDF, 100% RDF and 125% RDF). The results revealed that higher the fertilization (125% RDF) higher the biomass yield obtained with improved fodder quality parameters. Sorghum genotype CSV 32F had the highest green and dry fodder yield and it also had better digestibility in comparison to other genotypes. The highest nitrogen uptake was recorded in the genotype SPH 1891 which resulted in higher crude protein yield in this genotype but it noticed to have positive correlation with HCN (anti-nutrient) which is not desirable in livestock feed. In conclusion, use of 125% RDF and the genotypes CSV 32F would enhance the fodder yield due to comparatively better nitrogen uptake ability and its significant positive correlation with fodder quality parameters and growth attributes.

Key words : Nitrogen uptake, sorghum, biomass yield, fodder quality

All the essential plant nutrients play a vital role in plant growth and development. Less use of fertilizers leads to low yield and more use of fertilizers leads to soil, water and environment pollution. Nitrogen (N) is the most critical externally added input for any crop production system. Most of the population depends on fertilizers for food supply (Perchlik and Tegeder, 2017). The N used in commercial fertilizers is particularly soluble for easy uptake and assimilation by plants. Because of the simplicity of its storage and handling, N can easily be applied when plants need it most (Singh, 2018). The use of synthetic N fertilizers has eliminated a major elemental constraint with respect to enriching the soil stock of organic C and N originally managed by organic manure amendments, leguminous cultures and fallow periods. The formation of ammonia and thus synthetic N fertilizers by the Haber–Bosch process was one of the most important inventions of the 20th century, thus allowing the production of food for nearly half of the world population (Erisman *et al.*, 2008, Galloway *et al.*, 2018). Over 40 years, the amount of mineral N fertilizers applied to agricultural crops increased by 7.4-fold, whereas the overall yield increase was only 2.4-fold (Tilman *et al.*, 2002). This means that N use efficiency, (NUE) which may be defined as the yield obtained per unit of available N in the soil (supplied by the soil + N fertilizer) has declined sharply. NUE is the product of absorption efficiency (amount of absorbed N/quantity of available N) and the utilization efficiency (yield/absorbed N). For a large number of crops, there is a genetic variability for both N absorption efficiency and for N utilization efficiency (Hirel *et al.*, 2007). It is strongly involved in all of the plant metabolic processes and its rate of uptake and partition is largely determined by supply and demand during the various stages of plant growth (Delogu *et al.*, 1998). Moreover, the occurrence of interactions between the genotype and the level of N led to the conclusion that the best performing crop varieties at high N fertilization input are not necessarily the best ones when the supply of N is lower. This is mainly because breeding for most crops has been conducted over the last 50 years in the presence of high mineral fertilization inputs, thus missing the opportunity to exploit genetic differences under a low level of mineral or organic N fertilization conditions (Hirel *et al.*, 2011). Sorghum (*Sorghum bicolor* L.) is one of important crops and ranks at the fifth world's widest spread after wheat, rice, maize, and barley. Sorghum is one of the cereal crops consisting of forage and grains which has potential to be used for fodder (Dahir *et al.*, 2015). Optimizing N rate to utilize the full potential of sorghum genotypes/cultivars allows improved N use effciency and maximum economic returns to the farmers. Further, cultivar differences in nitrogen (N) use efficiency and their strategy of adaptation are not well investigated (Singh *et al.*, 2018). Growing interest in enhancing fodder sorghum productivity along with better quality and greater return from fertilizer N necessitates the need to evaluate comparative performance of genotypes. This information would, thereby, help in developing high yielding sorghum cultivars with more specific N management systems to enhance N use efficiency and the use of such cultivars having higher NUE under field conduction may help reduce the production costs, and nitrate-N contamination.Therefore, the present study was formulated with the aimed to quantify the nitrogen uptake and its association with the biomass yield in single cut sorghum genotypes.

MATERIALS AND METHODS

A field experiment pertaining to genotype and fertilizer application effects on fodder yield and N uptake was conducted during the *Kharif* season of 2019 at the research farm of Forage and Millet Section, Department of Plant Breeding and Genetics, PAU, Ludhiana. The experimental site is situated at 30^{o}54?N latitude and 75^{o}48?E longitude with an altitude of 247 meters above the mean sea level. The meteorological data for the crop season on standard meteorological week basis, as obtained from meteorological observatory of the Punjab Agricultural University are presented in Figure 1. The crop received a total rainfall of 787.4 mm. The texture of the experimental soil was sandy loam with pH 7.8, low in available nitrogen 184 kg/ha, low in available phosphorus 16.8 kg/ha and high in available potassium 246 kg/ha. The experiment was laid out in factorial randomized completely block design and each treatment combination was replicated thrice. The twelve treatment combinations comprised of four single cut forage sorghum genotypes and (SPH 1890, SPH 1891, CSV 30F and CSV 32F) and three fertility levels *viz*. 75, 100 and 125 per cent of recommended dose of fertilizer (RDF). The crop was sown on 20 June 2019 in a well-prepared seedbed in 25 cm apart rows using a seed rate of 40 kg/ha. The recommended dose of fertilizer (100%) for forage sorghum is 100 kg N, 20 kg P_2O_5 and 25 kg K_2O (in potassium deficient soils) per hectare. Half dose of nitrogen and full dose of phosphorus were applied as basal as per treatment levels. Remaining half dose of nitrogen was top-dressed after first irrigation at crop knee height stage for the respective treatments. The crop was raised with standard agronomic package of

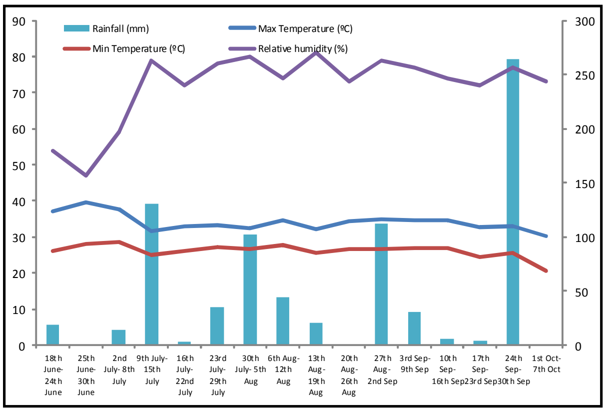

Fig. 1. Weekly weather data pertaining to temperature (°C), relative humidity (%) and rainfall (mm) during the crop season of 2019.

practices. At 50% flowering stage, the crop was harvested and the data on green fodder yield and yield attributes was recorded. The plant samples were also taken at 50% flowering stage for CP and IVDMD analysis. Plant samples collected after harvest were sun dried and then completely dried in hot air oven till a constant weight was obtained. This dried plant material was ground using Willy grinder to a uniform mesh size and used for the estimation of quality traits *i.e.* crude protein (CP), and in-vitro dry matter digestibility (IVDMD) by the method proposed by Kjeldhal's method (AOAC, 1970), and Tilley and Terry (1963), respectively. Yield and yield related parameters were recorded to find correlation with fodder quality traits. The data were analyzed by using computer software programme 'OPSTAT' available on CCS Haryana Agricultural University website (Sheoran *et al.*, 1998). The results are presented at five per cent level of significance (P=0.05) for making comparison between treatments.

RESULTS AND DISCUSSION

Biomass Yield

Results illustrated in Table 1 show significant differences in green and dry fodder yield among the different single cut sorghum genotypes under different fertility treatments. The higher green fodder yield of 624 q/ha and the dry fodder yield of 167.3 q/ha was recorded in CSV 32F followed by SPH 1891 with 520.1 q/ha and 145.7 q/ha green and dry fodder yield, respectively. Application of 125% RDF achieved maximum green fodder yield which accounted 14 and 6 per cent higher over 75% and 100% RDF, respectively. The same trend as that of green forage yield was observed for dry fodder yield of sorghum. The highest values of the character were produced by

TABLE 1
Effect of different treatments on biomass yield of sorghum genotypes

Treatments	Green fodder yield (q/ha)	Dry fodder yield (q/ha)	Plant height (cm)	L : S
Variety				
SPH 1890	401.8	108.8	230.2	0.32
SPH 1891	520.1	145.7	217.6	0.30
CSV 30F	429.4	116.7	248.8	0.49
CSV 32F	624.0	167.3	264.8	0.35
C. D. (P=0.05)	30.2	9.7	15.1	0.06
Fertility level				
75% RDF	460.5	124.3	253.5	0.36
100% RDF	495.8	136.3	266.7	0.35
125% RDF	525.2	143.2	274.1	0.39
C. D. (P=0.05)	26.2	8.4	NS	NS

application of the highest fertility level (125% RDF). Subsequently, the lowest value of the character was recorded with application of the lowest level *i.e.* 75% RDF. The magnitude of increase in dry fodder yield with 125% RDF over 75% RDF and 100% RDF was 15 and 5 per cent, respectively. Satpal *et al*., (2019) also reported the increasing response of forage sorghum in terms of fodder yield with increasing levels of fertility from 75 to 125%.

Dry yield is fundamental for vital carbohydrate components in forage crops to provide energy for livestock. Yet, the increase in dry forage yield (q/ha) with increased fertility levels could be attributed to the high response by forage sorghum crop to higher fertilizer levels. Further, this might have accelerated the meristematic activity, vegetative growth and consequently into increased plant height and leaf to stem ratio (Table 1) which eventually resulted in increased green and dry fodder yields of forage sorghum genotypes. The increase in fertilization showed non-significant increase in plant height and leaf to stem ratio. The genotype CSV 32F was entailed with significantly higher plant height followed by CSV 30F and these two genotypes take approximately 108 days to 50% flowering. However, opposite was observed in L:S ratio in CSV 32F (0.35) and CSV 30F (0.49).

The SPH 1891 took minimum days to 50% flowering and thereby, the genotype was noticed with lower plant height as compared to rest of the genotypes. Even though the plant height was shorter in SPH 1891, it showed second highest green and dry fodder yield and this might be due to its hereditary higher yielding biomass potential. Considering, the deteriorating soil conditions, attesting the most appropriate N quantity and role to maximize the yield in summer forage crops is agronomically and economically important. Similarly, Kaur and Satpal (2019) in a multi-location experiment obtained highest green and dry fodder yield of sorghum genotypes by increasing fertility level upto 125% of RDF. According to Afzal, *et al.*, 2012, increasing the N dose from zero to 50, 75, and 100 kg N/acre increased the dry weight of sorghum forage. Also, Sharajabian and Soleymani, 2017, obtained the highest total dry matter of forage sorghum (*Sorghum bicolor* L.) by addition of the top N level (240 kg N/ha).

Nitrogen content and uptake

The N content (Table 2) in single cut forage sorghum genotypes was significantly affected due to fertilizer application. Significantly higher N content (1.01%) in dry fodder and uptake (147.0 kg/ha) by the sorghum forage crop at harvest were registered when crop was fertilized with 125% RDF. Application of higher rate of fertilizers met requirement of plants at different growth stages of crop resulting in higher uptake of nitrogen by plants (Table 2). The increase in nitrogen content under 125% RDF was 26 and 11 per cent and uptake was 49 and 16 per cent over 75% RDF and 100% RDF, respectively. The probable reason might be that the soil was unable to supply nitrogen to the crop in sufficient quantity needed for

TABLE 2
Effect of different treatments on forage quality of sorghum genotypes

Treatments	N (%)	Crop N uptake (kg/ha)	CP (%)	Crude protein yield (q/ha)	IVDMD (%)	HCN (ppm)
Variety						
SPH 1890	0.82	89.9	5.2	5.6	48.5	9.7
SPH 1891	1.15	169.0	7.2	10.6	38.0	14.7
CSV 30F	0.77	89.4	4.8	5.6	44.2	11.6
CSV 32F	0.88	147.6	5.5	9.2	47.6	13.3
C. D. (P=0.05)	**0.06**	10.3	0.4	0.64	2.8	2.0
Fertility level						
75% RDF	0.79	98.5	5.0	6.2	41.7	13.4
100% RDF	0.92	126.5	5.7	7.9	44.3	10.2
125% RDF	1.01	147.0	6.3	9.2	47.8	13.4
C. D. (P=0.05)	**0.05**	8.9	0.3	0.56	2.5	1.7

optimum growth. Application of the nitrogen fertilizer cured this deficiency and reflected in the increase in nitrogen content in plant. Similar increase in nitrogen content and uptake by sorghum due to nitrogen levels was observed by Maranville, *et al.*, 2002.

The N content was 0.83, 1.15, 0.77 and 0.88 for SPH 1890, SPH 1891, CSV 30F and CSV 32F, respectively (Table 2). Among forage sorghum genotypes, SPH 1891 had more N uptake than CSV 30F (which was recorded with higher green and dry fodder yield). This might indicate that the genotypic variation at genetic level also plays role in nitrogen uptake and its utilization efficiency in terms of plant growth characters. Therefore, even though nitrogen uptake was more in SPH 1891 but the nitrogen utilization efficiency would be better in CSV 30F.

Quality parameters

The quality parameters like crude protein, hydrogen cyanide (HCN) and *In vitro* dry matter digestibility (IVDMD) were significantly influenced due to different fertility levels (Table 2). The evaluation of forage for crude protein is a matter of great importance as crude protein is essential for maintenance and production of new tissues. The crude protein content in dry fodder of sorghum was significantly increased as the rate of nitrogen application increased. The similar trend was observed in crude protein yield (q/ha). The highest CP of 7.2% was seen in SPH 1891 followed by CSV 32F (5.5%). The crude protein yields of 10.6 q/ha and 9.23 q/ha were noticed in SPH 1891 and CSV 32F, respectively (Table 2) as these genotypes as discussed earlier fetched higher green and dry fodder yields (Table 1).

Adequate fertilization has been suggested to improve not only the yield but also the crude protein content and consequently the protein yield of single cut forage sorghum. Our ?ndings hereby highlight that, agronomy practices that secure increasing the quality content in high yielding fodder species such as sorghum are bene?cial to improve forage palatability and digestibility. Similar remarks on the increased crude protein content with increased N levels were reported by Ibrahim, *et al.*, 2016 and Naik, 2016. Therefore, the *invitro* dry matter digestibility was noticed to improve with increase in dose of fertilizer from 75% to 125% RDF (Table 3). The higher yielding genotype CSV 32F found to higher digestibility compared to other genotypes. Oberoi and Kaur, 2019, reported that increased levels of nitrogen in fodder oats increases the IVDMD. Hence, in the present study, it is suggested that higher fertilizer application increased the nitrogen levels in the plant which is the constituent of amino acids and protein and it might lead to decrease the pectin, cellulose and hemicellulose content which are major constituents of fibre and which thereby, showed increase in IVDMD.

Moreover, the higher nitrogen uptake as seen earlier in the discussion not only helps in enhancing the yield but also it helps in improving the digestibility by mobilizing more nitrogen towards protein synthesis then in formation of fibrous material in the fodder crop sorghum. On the contrary, the HCN content, which is the antinutrient in sorghum, recorded to increase in the genotypes showing the more nitrogen uptake (Table 2). However, the noticed content of HCN in all the genotypes and with the applied doses of fertilizers is much below the permissible limit and this anti-quality does not affect much to quality in comparison to other benefits in terms of biomass yield and crude protein content resulted from increased nitrogen uptake (Table 1 and 2).

Correlation

The correlation of nitrogen uptake with the biomass yield and fodder quality in four single cut sorghum genotypes was analysed and was presented in Table 3. The studies on the correlation of traits are important, as this will be helpful in selection of desirable fodder quality traits. The data shows that the nitrogen uptake showed positive and strong correlation with green and dry fodder yield in all the genotypes used in the present investigation. The other growth parameters

TABLE 3
Correlation of nitrogen uptake with biomass yield and fodder quality attributes of sorghum genotypes

Varieties	Correlation of nitrogen uptake							
	GFY	DFY	Plant height	Days to flowering	L : S	CP	IVDMD	HCN
SPH 1890	0.876	0.867	0.394	0.797	-0.303	0.722	0.220	-0.449
SPH 1891	0.871	0.845	0.036	0.838	0.346	0.947	0.755	0.789
CSV 30F	0.716	0.757	0.543	0.805	0.233	0.696	0.853	-0.462
CSV 32F	0.502	0.469	0.903	0.885	0.630	0.894	0.575	-0.173

also had positive correlation with the uptake of nitrogen. The CSV 32F recorded with higher positive correlation of nitrogen uptake potential with plant height, leaf to stem ratio and days to flowering. The fodder quality attributes *i.e*. crude protein and invitro dry matter digestibility were found to be positively influenced with the nitrogen uptake. The higher CP with higher nitrogen uptake could indicate lower fibre content in fodder crops and could be taken as one of the selection criteria. The antinutrient HCN noticed to have negative correlation with the nitrogen uptake in three of the single cut sorghum genotypes (SPH 1890, CSV 30F and CSV 32F) which indicates that if there is more nitrogen uptake the risk due to hydrogen cyanide poisoning would be lesser. However, the sorghum genotype SPH 1891 would lead to increase in HCN content with increase nitrogen fertilization and its uptake by the plant which is the risk to livestock.

CONCLUSION

From the present investigation, it could be concluded that the use of 125% RDF and the genotypes CSV 32F would enhance the fodder yield due to comparatively better nitrogen uptake ability and significantly higher positive correlation was noticed between them. The genotype might be due to its inherited biological nitrification inhibition potential found to have improved quality in terms of crude protein and digestibility.

REFERENCES

Afzal, M., A. Ahmad and A.H. Ahmad, 2012 : Effect of nitrogen on growth and yield of sorghum forage (*Sorghum bicolor* (L.) Moench cv.) under three cuttings system. *Cercet. Agron. Mold*., **45**: 57-64.

AOAC, 1970 : *Official Methods of Analysis*. Association of Official Analytical Chemists. 11th edition. Washington, D.C.

Dahir, M., K. X. Zhu, X. N. Guo, W. Aboshora and W. Peng, 2015 : Possibility to Utilize Sorghum Flour in a Modern Bread Making Industry. *J. Acad. Ind. Res*., **4** : 128-135.

Delogu, G., L. Cattivelli, N. Pecchioni, D. De Falcis, T. Maggiore and A. M. Stanca, 1998 : Uptake and agronomic ef?ciency of nitrogen in winter barley and winter wheat. *Eur. J. Agron*., **9**: 11-20.

Erisman, J. W., M. A. Sutton, J. N. Galloway, Z. Klimont, W. Winiwarter, 2008 : How a century of ammonia synthesis changed the world. *Nat. Geosci*., **1**: 636-639.

Galloway, J. N., A. R. Townsend, J. W. Erisman, M. Bekunda, Z. Cai, J. R. Freney, L. A. Martinelli, S. P. Seitzinger and M. A. Sutton, 2008 : Transformation of the nitrogen cycle: *Recent trends, questions, and potential solutions. Sci*., **320**: 889-892.

Hirel, B., T. Tetes, P. J. Lea and F. Dubois, 2011 : Improving nitrogen use efficiency in crops for sustainable agriculture. *Sustainability*, **3**: 1452-1485.

Hirel, B., J. Le Gouis, B. Ney and A. Gallais, 2007: The challenge of improving nitrogen use efficiency in crop plants: Towards a more central role for genetic variability and quantitative genetics within integrated approaches. *J. Exp. Bot*., **58**: 2369-2387.

Ibrahim, A. M., E. M. I. Zeidan, H. G. M. Geweifel, I. M. Abd El-Hameed and S. A. Mahfouz, 2016 : In?uence of planting density and nitrogen fertilizer levels on fresh forage yield and quality of some forage sorghum genotypes. *J. Agric. Res*., **43**: 729–743.

Kaur, M. and Satpal, 2019 : Yield and economics of single cut sorghum genotypes as influenced by different fertilizer levels. *Int. J. Agric. Sci.,* **11**(5): 7971-7973.

Maranville, J. W., R. K. Pandey and S. Sirifi, 2002 : Comparison of nitrogen use efficiency of a newly developed sorghum hybrid and two improved cultivars in the Sahel of West Africa. *Commun. Soil. Sci. Plant Anal*., **33**: 1519-1536.

Naik, G., 2016 : E?ect of di?erent fertility levels on growth and fodder yield of sweet sorghum. M.Sc. thesis, Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India.

Oberoi, H. K. and M. Kaur, 2019 : Yield, growth and proximate analysis of multi-cut fodder sorghum genotypes with different doses of nitrogen. *Forage Res*., **45**: 136-139.

Perchlik, M. and M. Tegedu, 2017 : Improving plant nitrogen use efficiency through alteration of amino acid transport processes. *Plant Physiol*., **175**: 235-247.

Satpal, J. Tokas, K. K. Bhardwaj, S. Devi, P. Kumari, S. Arya, Neelam and S. Kumar, 2019. Evaluation of forage sorghum for production, productivity and quality at different fertilizer levels. *Forage Res*., **45**(1): 64-68

Shahrajabian, M. H. and A. Soleyman, 2017 : Responses of physiological indices of forage sorghum under different plant populations in various nitrogen fertilizer treatments. *Int. J. Plant Soil Sci*., **15**: 1-8.

Sheoran, O. P., D. S. Tonk, L. S. Kaushik, R. C. Hasija and R.S. Pannu. 1998. Statistical Software Package for agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D. S. Hooda and R.C. Hasija Department of Mathematics & Statistics, CCSHAU, Hisar 139-143.

Singh, A., A. Kumar, A. Jaswal, M. Singh and D.S. Gaikwad, 2018 : Nutrient use efficiency concept and interventions for improving nitrogen use efficiency. *Plant Arch*., **18**: 1015-1023.

Tilley, J. M. A. and R. A. Terry, 1963 : A two-stage technique for in vitro digestion of forage crops. *J. British Grassland Soc.,* **18**: 104-111.

Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor and S. Polasky, 2002 : Agricultural sustainability and intensive production practices. Nature, **418**: 671-677.