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FOLIAR SPRAY OF GROWTH REGULATORS AND MINERAL NUTRIENTS FOR ENHANCED PRODUCTIVITY AND PROFITABILITY OF SINGLE CUT FORAGE SORGHUM IN SEMI-ARID REGIONS OF INDIA

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SUMMARY

A field experiment was conducted at Forage Section Research Farm, CCS Haryana Agricultural University, Hisar, during *kharif* season of 2019 and 2020 on single-cut forage sorghum to quantify the impact of plant bio-regulators on forage productivity and quality of sorghum grown as rainfed crop. Eight treatments including foliar application of plant bio-regulators included 2% urea, 2% NPK (18-18-18), 2% potassium nitrate (KNO_3), 1 ppm silicic acid, 2 ppm silicic acid and 100 ppm salicylic acid at panicle initiation and flag leaf emergence stage were compared with no spray as well as water spray in randomized block design in three replicates. The application of PBRs increased green fodder yield by 13.75-19.73 per cent over control. On pooled mean basis, the highest green and dry fodder yield of 52.31 and 13.74 t/ha, respectively was recorded with application of 2% NPK (18-18-18). Among treatments, the crude protein content in dry fodder was not affected significantly, however, maximum crude protein yield was estimated with the application of 2% water soluble fertilizer NPK (18-18-18) which was on a par with urea @ 2%, KNO_3@ 2%, silicic acid 2 ppm and 100 ppm salicylic acid. Beside this, there was a substantial reduction in the HCN content due to foliar application of 2% KNO_3. On pooled mean basis, foliar application of PBRs /nutrients improved the BC ratio which ranged from 1.62 to 1.70 with KNO_3, 2% NPK (18-18-18), 2% urea, 1 and 2 ppm silicic acid and 100 ppm salicylic acid spray. The BC ratio with the foliar application of 2% KNO_3, 2% NPK (18-18-18), 2% urea, 2 ppm silicic acid and 100 ppm salicylic acid was 7.28, 9.27, 12.58, 11.26 and 11.92 per cent higher over control (no foliar spray, only recommended dose of fertilizer @ 75 kg N+30 kg P_2O_5+ 30 kg K_2O/ha), respectively on pooled mean basis. Foliar application of KNO_3 presents a viable option for improving sorghum fodder productivity and its quality under rainfed/ moisture stress situation.

Key words: Green fodder yield, HCN, KNO_3, plant bio-regulators, salicylic acid, silicic acid, sorghum, urea spray

Sorghum [(*Sorghum bicolor* L.) Moench] is the most widely grown forage crop of India (2.6 m ha) with single and multi-cut sorghums accounting for 0.6 and 2.0 m ha acreage, respectively (Prabhakar Babu, 2018). Single cut forage sorghum is grown mainly in the states of Punjab, Haryana, Delhi, Uttar Pradesh and adjoining areas of Madhya Pradesh etc. (Harinarayana *et al.* 2005) under rain fed situation. As a matter of fact, forage sorghum and pearl millet are seen as alternative to maize in rain fed areas (Bhattarai *et al.,* 2019). High dry fodder yields (13.7 t/ha) of forage sorghum 'HJH 1513' realized under favourable soil moisture and nutrition (Satpal *et al.,* 2020) were drastically reduced under moisture stress besides enhancing hydrocyanic acid (HCN) contents (Shehab *et al.,* 2020) to a level that may prove lethal to livestock feeding on it (Karthika and Kalpana, 2017). With the estimated coverage of more than 50% of all arable

lands by abiotic stresses (water-scarcity and salinity) by 2050 (Srivastava and Gupta, 2015), there is a need to look for potential mechanisms by which the adverse impacts of drought on both productivity and its quality of produce could be overcome to a major extent. Exogenous application of growth regulators like salicylic acid in drought stressed sorghum (Arivalagan and Somasundaram, 2016) and wheat (Maghsoudi Kobra *et al.,* 2019), silicic acid [$Si(OH)_4$)] in finger millet (Sandhya *et al.,* 2020) and potassium nitrate in barley (Fayez and Bazaid, 2014) were found to improve the osmotic adjustment and antioxidant activities. Foliar spray of urea (Kheirabadi *et al.,* 2012), NPK nutrients (Shabbir *et al.,* 2016) were found to enhance the crop biomass production by quick nutrient supply to plants that is otherwise has restricted uptake possibilities from soil that is starved of moisture. Even water sprays were found to bring some relief from the drought in pigeon pea (Selvi *et al*., 2009). It is in this context, studies were made to assess the impact of various growth regulators and mineral nutrients' foliar spray on performance of single cut forage sorghum under rain fed conditions.

MATERIALS AND METHODS

The field experiment was carried out the during the *kharif* seasons of 2019 and 2020 at All India Coordinated Sorghum Improvement Project centre, Forage Section, Department of Genetics & Plant Breeding CCS Haryana Agricultural University, Hisar. Hisar with a sub-tropical and semi-arid climate is situated between 29^0 1′ N Latitude, 75^{0}46′ E Longitude at an altitude of 215.2 m above mean sea level. Hisar has a sub-tropical steppe (BSh) climate with a low annual rain fall (459 mm) and has an average temperature of 25.1°C with lowest and highest temperatures of 5.5 (January) to 41°C (June). The weather situation during the crop season during both the years of study was almost similar with respect to temperature and relative humidity (Fig. 1 and 2), however, more rainfall was received during 2019 (299.0 mm) than 2020 (227.3 mm) crop period.

Experimental soil was classified texturally as sandy loam. Soil samples were collected before start of the experiment each year from plough layer depth and were subjected to chemical analysis as per standard procedures. The analysis revealed that the soil was non- saline (EC: 0.28 & 0.26 dS/m) with pH above neutral range (7.8 & 7.7) and was rated as low for organic carbon (0.52 & 0.48%), available nitrogen (130 & 151.5 kg/ha) and medium for available

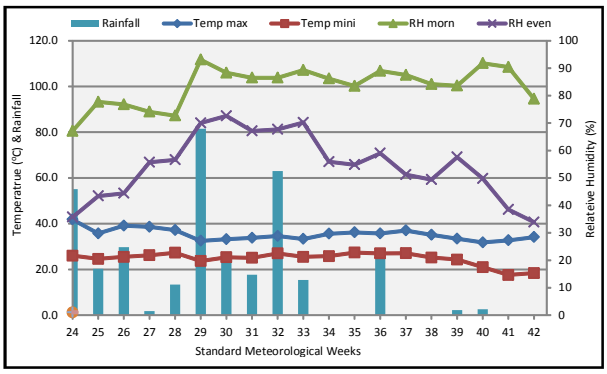

Fig. 1. Weekly weather parameters during *Kharif* 2019.

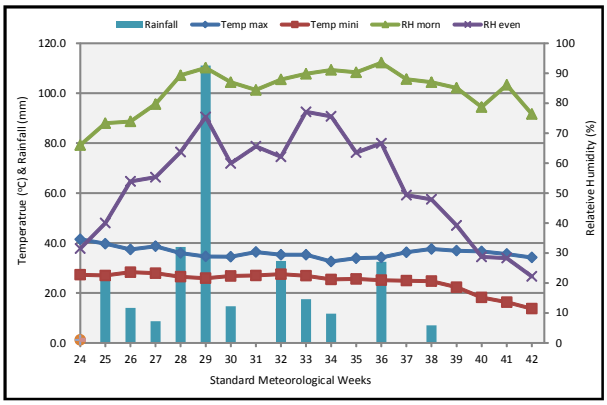

Fig. 2 Weekly weather parameters during *Kharif* 2020.

phosphorus (14.1 & 13.2 kg/ha) and potassium contents (232.0 & 253.1 kg/ha) during 2019 & 2020.

Experiment comprising of eight foliar spray treatments (no spray-control, water spray, 2% urea, 2% NPK (18-18-18), 2% KNO_3, 1, 2 ppm silicic acid and 100 ppm salicylic acid) given at panicle initiation and flag leaf emergence stage (using 500 L/ha of spray fluid/water) were evaluated in randomized complete block design with three replications. Single cut sorghum (*cv*. HC 308) was sown in soiled rows spaced 25 cm apart using 50 kg seed/ha on 24 June 2019 and 18 July, 2020 and was harvested at 50% flowering stage. Crop received 50-30-30 kg/ha of N-P_2O_5-K_2O as basal dose and 25 kg/ha of N was top dressed at 30 days after sowing. Urea and DAP are the sources of N and P and MOP was used as source of K. Crop was kept weed free throughout the growing season through one hand weeding at 25 days after sowing. Other management practices were adopted as per recommendations of sorghum crop for the region. The data on growth parameters *viz*., plant height, plant stand and leaf-stem ratio and yield (green fodder and dry matter) were recorded at the time of harvest. HCN content was estimated using spectrophotometer by Gilchrist *et al*., (1967) and was calculated from standard curve. The samples for estimation of HCN

were taken at 30 DAS from the portion of the plant immediately below the uppermost leaf collar. Plant samples were taken at harvest (50% flowering stage) 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 of nitrogen concentration by micro-Kjeldhal's method (AOAC,1995) and *in-vitro* dry matter digestibility (IVDMD) by the method proposed by Barnes *et al.* (1971). Data was analyzed by OPSTAT software available at CCS HAU Hisar website and the least significant difference was used to compare treatment means (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

Growth

Data on plant height (cm) and plant stand at fodder harvest as influenced by foliar spray treatments is given in Table 1. Plant height was not significantly impacted by foliar spray treatments during 2019. However, during 2020, significant improvements in plant height were brought with 2% water soluble fertilizer NPK (18-18-18) sprays over no spray control, water spray and 1% silicic acid. On mean basis of two years, 2% NPK sprays has increased the plant height of forage sorghum crop by 26.8 cm over no spray control. The increase in plant height was greater during 2019 having favourable rainfall than 2020 with low rain fall. All other foliar spray treatments though brought improvements in plant height over no spray control, the increase could not reach statistical significance level during 2019 and thus they have at par plant height values as that of not only control but also with that of urea spray. However, during 2020, 2% NPK, 2% urea, silicic acid (1 ppm) and silicic acid (2 ppm) sprays have brought significant improvements in plant height over no spray control and water spray. Low rainfall received during 2020 might have resulted in better water status maintenance with 2% NPK, 2% urea, silicic acid (1 ppm) and silicic acid (2 ppm) spray and thus has brought improvement in plant height. Similar effects of water spray on pigeon pea reported by Selvi *et al.* (2009) supports the current findings. Better N / NPK nutrients supply to crop under moisture stress situation through urea, NPK spray might have improved plant height and thus proves a simple, low cost method for supplementary soil fertilization for a moisture stressed crop. Silicic acid spray by way of depositing silica on leaves might have contributed to stomata regulation and better leaf water status maintenance and thus improved plant height. Similar increases in plant height due to silicon application were reported by Gong *et al.* (2003). Under optimum soil moisture conditions of 2019 different sprays failed to influence the plant height significantly. Non-significant increases in tiller number due to silicic acid spray of current study are corroborated by the findings of Sandhya *et al.* (2020) with finger millet crop. In general, mean plant stand (000/ha) of 2019 (447.8) was 10.6% higher than that of 2020 (405.0) probably on account of lack of control on seed rate during sowing. Various spray treatments have brought significant increases in leaf: stem ratio than no spray control. Mean leaf: stem ratio values are highest with urea, NPK, KNO_3 and silicic acid (2 ppm) spray. Nutrient sprays have favored more leaves production/ prolonged maintenance of existing leaves and thus has higher leaf: stem ratio than control. Higher leaf weight ratio due to silicic acid application reported in current

TABLE 1
Effect of different foliar spray treatments on growth attributes of forage sorghum

Treatment	Plant height (cm)		Plant stand (000/ha)		Days to 50% flowering		Leaf : Stem ratio (pooled)
	2019	2020	2019	2020	2019	2020	
Absolute control (No spray)	261.6	251.9	377.8	422.2	91.3	86.7	0.23
Water spray	267.1	260.0	395.6	435.6	92.3	87.3	0.24
Urea spray @ 2%	286.2	279.3	426.7	466.7	92.7	87.7	0.26
NPK (18:18:18) @ 2% spray	286.4	280.6	404.4	462.2	92.7	88.3	0.26
KNO3 @ 2% spray	283.2	272.9	408.9	448.9	93.3	88.3	0.26
Silicic acid @ 1ppm	274.0	262.0	400.0	440.0	95.3	89.3	0.24
Silicic acid @ 2 ppm	289.1	272.6	422.2	462.2	96.0	89.7	0.26
Salicylic acid 100 ppm	278.3	273.4	404.4	444.4	93.7	88.7	0.25
C. D. (P=0.05)	NS	15.21	NS	NS	1.90	NS	0.02

TABLE 2
Effect of different foliar spray treatments on yield of fodder sorghum

Treatment	Green fodder yield (t/ha)			Dry fodder yield (t/ha) (t/ha)			Crude protein yield (t/ha): pooled	Digestible dry matter yield (t/ha) : Pooled
	2019	2020	Pooled	2019	2020	Pooled		
Absolute control (No spray)	47.22	40.17	43.69	11.40	9.74	10.57	1.01	5.32
Water spray	52.15	42.49	47.32	12.70	10.15	11.43	1.11	5.93
Urea spray @ 2%	53.33	48.97	51.15	13.34	13.28	13.31	1.41	6.95
NPK (18:18:18) @ 2% spray	54.46	50.16	52.31	14.31	13.17	13.74	1.46	7.19
KNO3 @ 2% spray	53.63	46.86	50.24	13.62	12.15	12.88	1.31	6.51
Silicic acid @ 1ppm	54.81	44.58	49.70	14.33	10.89	12.61	1.22	6.39
Silicic acid @ 2 ppm	55.92	45.69	50.80	14.97	11.52	13.24	1.38	6.90
Salicylic acid 100 ppm	55.26	46.15	50.71	14.48	11.47	12.98	1.33	6.74
C. D. (P=0.05)	4.94	5.47	4.28	2.02	1.22	0.60	0.17	0.68

TABLE 3
Effect of different foliar spray treatments on crude protein, IVDMD, HCN, nitrogen content and uptake of fodder sorghum (two year pooled data)

Treatment	Crude protein (%)	IVDMD (%)	HCN (µg/g) on fresh wt. basis	N content (%)	N uptake (kg/ha)
Absolute control (No spray)	9.61	50.30	120.5	1.54	162.7
Water spray	9.70	51.88	110.0	1.55	177.8
Urea spray @ 2%	10.61	52.23	119.5	1.70	225.8
NPK (18:18:18) @ 2% spray	10.65	52.35	110.2	1.70	234.4
KNO3 @ 2% spray	10.18	50.48	85.6	1.63	209.8
Silicic acid @ 1ppm	9.65	50.73	107.1	1.54	195.3
Silicic acid @ 2 ppm	10.39	52.08	98.6	1.66	221.3
Salicylic acid 100 ppm	10.24	51.95	105.9	1.64	213.5
C.D. (p=0.05)	NS	NS	3.32	NS	27.5

investigation was corroborated by the findings of Gong *et al.* (2003) in drought stressed wheat plants.

Fodder yield and fodder quality

Data on green, dry fodder yield (t/ha), N concentration (%), IVDMD (%) and HCN content (ppm) of forage sorghum as influenced by foliar spray treatments is given in Table 2. The data reveals that foliar spray treatments have marked influence on fodder yields (both green and dry) and N concentration of fodder. Except water spray and 1 ppm silicic acid spray, all other spray treatments have brought discernible improvements in fodder yields over no spray control. During 2019, maximum green fodder yield was recorded with silicic acid (2 ppm) and during 2020 maximum green fodder yield was recorded with NPK spray.

Higher plant height values and 10.6% higher plant stand and high rainfall received during 2019 was responsible for higher green and dry fodder yields as compared to 2020. Nutrient sprays best fodder

TABLE 4
Effect of different foliar spray treatments on economics of fodder sorghum (pooled data)

Treatment	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C
Absolute control (No spray)	36233	54612	18380	1.51
Water spray	37450	59151	21701	1.58
Urea spray @ 2%	37561	63940	26379	1.70
NPK (18:18:18) @ 2% spray	39495	65386	25891	1.65
KNO3 @ 2% spray	38677	62804	24127	1.62
Silicic acid @ 1ppm	37605	62122	24517	1.64
Silicic acid @ 2 ppm	37759	63504	25745	1.68
Salicylic acid 100 ppm	37593	63382	25789	1.69
C. D. (P=0.05)	-	4348	4348	0.08

productivity performance was probably ascribed to more N and K supply to foliage. Better water regulation by urea, NPK, silicic acid and salicylic acid spray are the reasons for superior performance. Similar increases in yield due to silica sprays in finger millet (Sandhya *et al.,* 2020) and sorghum (Flores *et al.,* 2018), urea spray in forage sorghum (Kheirabadi *et al.,* 2012) and

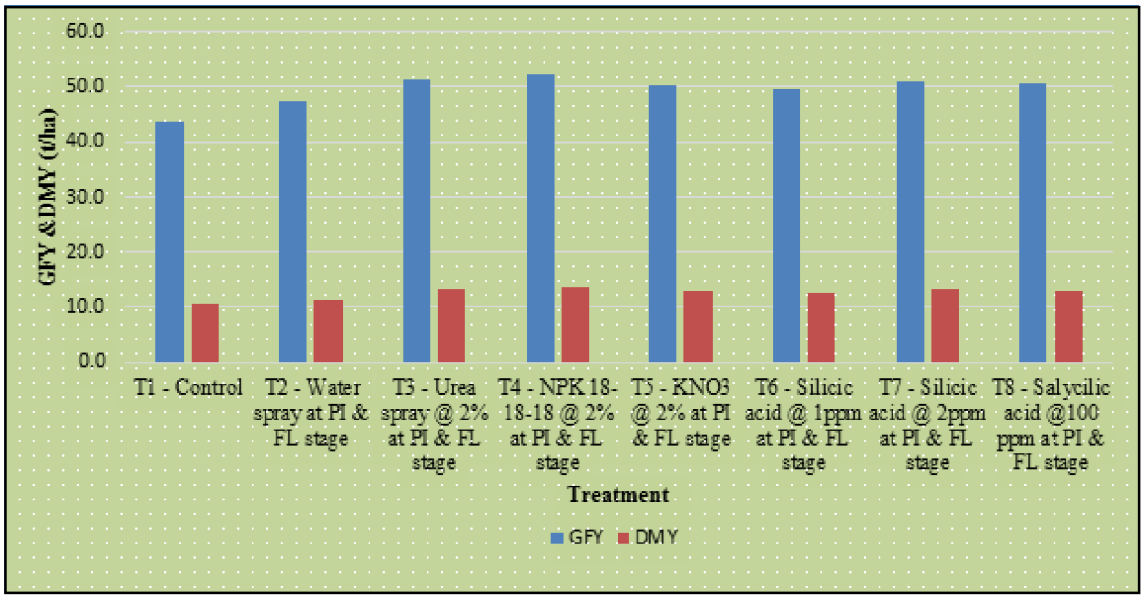

Fig. 3. Green fodder and dry matter yield of single-cut sorghum (Pooled mean of 2 year).

KNO_3 spray in barley (Fayez and Bazaid, 2012) supports the current findings.

Crude protein content and IVDMD (%) of forage sorghum was not affected significantly during both the years. However, numerically there was improvement in the spray treatments which was significantly reflected in the crude protein yield and digestible dry matter yield. Similar increases in protein yield of forage sorghum and maize due to foliar spray of urea (Kheirabadi *et al.,* 2012) supports the current study improvement in N concentration of forage sorghum. On pooled mean basis, maximum crude protein yield (1.46 t/ha) and digestible dry matter yield (7.19 t/ha) were recorded with the spray of 2% NPK (18-18-18) which were on a par with 2% urea, 2% KNO_3, 2 ppm silicic acid and 100 ppm salicylic acid.

The estimated HCN content at 30 days after sowing was highest in no spray control crop that is subjected to water stress during 2020 through 2019 has less water stress on pooled basis. Drastic reduction in HCN content due KNO_3 spray is the most striking observation of the study, though other treatments including water spray have recorded significantly lower HCN contents than no spray control. Similar results were also observed by Kaur *et al*. (2022). High HCN content of no spray control treatment of present study and its lower values due to growth regulators is corroborated by findings of Shehab *et al.* (2020). On pooled mean basis, maximum nitrogen uptake (234.4 kg/ha) was recorded with the spray of 2% NPK (18-18-18) which were on a par with 2% urea, 2% KNO_3, 2 ppm silicic acid and 100 ppm salicylic acid.

ECONOMICS

Economics data of forage sorghum cultivation as influenced by foliar spray treatments was given in Table 3. Mean gross returns were significantly increased with foliar spray of nutrients/ growth regulators. No spray control being at par with water spray has the lowest gross returns. Urea @ 2% spray has the highest net returns (Rs. 26379/ha) followed by 2% NPK spray and salicylic acid 100 ppm. Benefit cost ratio was best (1.70) with urea @ 2% spray followed by 100 ppm salicylic acid, silicic acid @ 2 ppm and water soluble fertilizer NPK (18:18:18) @ 2% spray. The BC ratio with the foliar application of 2% KNO_3, 2% NPK (18-18-18), 2% urea, 1 ppm silicic acid and 2 ppm silicic acid and 100 ppm salicylic acid was 7.28, 9.27, 12.58, 8.61, 11.26 and 11.92 per cent higher over control (no foliar spray, only recommended dose of fertilizer @ 75 kg N+30 kg P_2O_5+ 30 kg K_2O/ha), respectively on pooled mean basis.

CONCLUSION

Foliar spray of either of 2% urea, 2% NPK 18-18-18, 2 ppm silicic acid and 100 ppm salicylic acid at panicle initiation and flag leaf emergence stage was promising not only even under moisture stress conditions but also under favorable moisture conditions of Hisar as evident from fodder yields, fodder quality and economics perspective.

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REFERENCES

Arivalagan, M., and R. Somasundaram, 2016: Propiconazole and Salicylic acid alleviate effect of drought stress in sorghum (*Sorghum bicolor* L. Moench) through biochemical and some physiological characters. *Journal of Applied and Advanced Research*, **1**(3): 1-7. *doi.: 10.21839/jaar.2016.v1i3.26.*

Bhattarai, B., S. Singh, C.P. West, and R. Saini, 2019 : Forage potential of pearl millet and forage sorghum alternatives to corn under the water-limiting conditions of the Texas high plains: A review. Crop, Forage & Turfgrass Management, **5**: 1-12. *https://doi.org/10.2134/cftm2019.08.0058*.

Fayez, K.A. and S. A. Bazaid, 2014 : Improving drought and salinity tolerance in barley by application of salicylic acid and potassium nitrate. Journal of the Saudi Society of Agricultural Sciences, **13**(1): 45-55. *https://doi.org/10.1016/j.jssas.2013.01.001*.

Gilchrist, D.G., W.E. Lueschen and C.N. Hittle, 1967 : Revised method for the preparation of standards in the Sodium Picrate assay of HCN. *Crop Science*. **7**: 267-268.

Harinarayana, G., N.P. Melkania, B.V.S. Reddy, S.K. Gupta, K.N. Rai and P. Sateesh Kumar, 2005 : Forage Potential of Sorghum and Pearl Millet.

Karthika, N. and R. Kalpana, 2017 : HCN Content and forage yield of multi-cut forage sorghum under different organic manures and nitrogen levels. *Chemical Science Review and Letters,* **6**: 1659-1663.

Kaur, M., Oberoi, H.K., Gangaiah, B., and Satpal, 2022 : Effect of foliar application of plant bio-regulators to mitigate the adverse effect of drought on productivity and quality of single cut fodder sorghum in north-west Punjab in India. *Agriculture Research Journal,* **59**(2): 216-220.

Maghsoudi Kobra, EmamYahya, Ashraf Muhammad, Arvin Mohammad Javad, 2019 : Alleviation of field water stress in wheat cultivars by using silicon and salicylic acid applied separately or in combination. *Crop and Pasture Science,* **70**: 36-43. *https://doi.org/10.1071/CP18213.*

Prabhakar Babu, 2018 : Forage Crop Research Contribution to the Indian fodder production: Business opportunities for seed industry. *https://www.millets.res.in/ aicsip18/presentations/Stakeholders_interactionDay1/Forage_Opportunities.pdf.*

Satpal, B. Gangaiah, N. Kumar, S. Devi, N. Kharor, K. K. Bhardwaj, P. Kumari, D. S. Phogat and Neelam. 2020. Performance of single-cut forage sorghum cultivars at different fertilizer levels. *Forage Res.,* **46**(2): 202-207.

Shehab A. A., Yao Luhua, Wei Liangliang, Wang Dengke, Li Yang, Zhang Xuefeng, GuoYanjun. 2020 : The increased hydrocyanic acid in drought-stressed sorghums could be alleviated by plant growth regulators. *Crop and Pasture Science,* **71**: 459-468.

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 & R.C. Hasija, Department of Mathematics Statistics, CCS HAU, Hisar (139-143).

Srivastava, M.K and Gupta, C.K. 2015: Biochemical evaluation of forage sorghum for stress tolerance. In: Proceedings The 23rd International Grassland Congress (Sustainable use of Grassland Resources for Forage Production, Biodiversity and Environmental Protection), New Delhi, India 20-24 November, 2015. (Editors: M. M. Roy, D. R. Malaviya, V. K. Yadav, Tejveer Singh, R. P. Sah, D. Vijay, and A. Radhakrishna) Published by Range Management Society of India. *https://uknowledge.uky.edu/igc/23/4-1-2/11.*