Indian Journal of Agronomy **65** (1): 100–106 (March 2020)

Research Paper

Effect of pre-sowing seed inoculation with liquid biofertilizers on fodder yield and quality of sorghum (*Sorghum bicolor*)

HARPREET KAUR OBEROI[1], GULAB PANDOVE[2] AND ANUREET KAUR[3]

Punjab Agricultural University, Ludhiana, Punjab 141 004

Received: July 2019; Revised accepted: January 2020

ABSTRACT

An experiment was carried out during the rainy (*kharif*) seasons of 2016 and 2017 at 2 locations of Punjab (Ludhiana and Bathinda), to study the effect of N-fixer (*Azotobacter* species) and P-solubilizers (*Sphingobacterium* species, *Burkholderia* species and *Streptomyces badius*) inoculations and their interactions, in the presence of recommended dose of fertilizer (RDF) on 'SL 44' single-cut forage sorghum [*Sorghum bicolour* (L.) Moench]. A total of 9 liquid microbial inoculant combinations were used as seed treatment before sowing. All the microbial treatments along with chemical fertilization resulted in non-significant numeric increase in yield and growth of sorghum at both the locations in 2 consecutive years. The dual inoculation, i.e. *Azotobacter* species + *Burkholderia* species along with RDF resulted in 21.5% and 16.8% percent increase in crude protein (CP) and *in-vitro* dry-matter digestibility (IVDMD) over the control, observed from 2 locations pooled mean respectively. Similar combination of biofertilizer with recommended dose of fertilizer resulted in lower acid detergent fibre (ADF) and neutral detergent fibre (NDF) content of 40.40% and 53.53% respectively. The hydrocyanic acid (HCN) production was also noticed to be lowered down with the use of liquid dual inoculum of *Azotobacter* species + *Burkholderia* species. Green fodder yield (GFY) had positive significant correlation with all yield, growth and quality parameters, whereas negative correlation with HCN (–0.09), ADF (–0.34) and NDF (–0.18). Dry-fodder yield (DFY) exhibited the highest significant correlation coefficient with IVDMD (0.92) followed by CP (0.71). The results of correlation also indicated that the plant height should be given due importance as it showed significant correlation with dry-fodder yield. Therefore, there was synergetic effect of nitrogen-fixing and phosphate-solubilizing microbial inoculants on fodder quality improvement of sorghum.

Key words : Correlation, Fodder quality, Liquid biofertilizers, Sorghum, Yield

For better efficiency of livestock, only quantitative production of fodder is not important, but the quality also plays its role. The specific role of primary essential plant nutrients is related to enhancing growth in fodder and forage crops. Optimum nitrogen nutrition improves leaf: stem ratio, succulency and palatability of forage crops. It increases crude protein, metabolizable energy and narrowed the nutritive ratio of fodder. Conventionally, the forage crops are cultivated on marginal lands characterized by low-nutrient supply. In Indian soils, the most limiting and key nutrient is nitrogen required for the crop growth (Crawford *et al.,* 2018). Sorghum ranks first among the cereal fodder crops and for good production and growth it requires high amounts of N fertilizer. It absorbs nutrients in large amount throughout the growth period (Manjunath *et al.*, 2013) and the use of chemical fertilizers for fulfilling the nutrient requirement for growth have adverse effect on fertility of soil.

For successful cultivation, nutrient management is important and the quantity and quality of crops can be affected by biofertilizers (Kachroo and Razdan, 2006). In agriculture, the nitrogen-fixing bacteria especially *Azotobacter* and *Azospirillum* increase the yield in cereals and also exerts many positive effects on the crop when various biotic and abiotic factors influence crop growth and yield (Saleem *et al.,* 2015). Biofertilizers applied to either soil, plant surface or seed results in increase of the supply or availability of primary growth nutrients to the host plant (Yadav *et al.,* 2007).

It has been estimated that half of the applied nitrogen is lost in various processes (Pindi, 2012). Further, the use of chemical fertilizers is not economical for resource-poor

[1]**Corresponding author Email:** harpreetoberoi@pau.edu
[1]Nutritionist (Forage), Forages, Millets and Nutrition Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana 141 004; [2]Microbiologist (Soil Science), [3]Agronomist, Punjab Agricultural University, Regional Research Station, Bathinda, Punjab 151 005

farmers. It is obvious that synthetic fertilizers cannot be put out from agriculture without compromising the low yield but these must be integrated with biofertilizers. The use of nitrogen-fixing, free-living bacteria could be one of the alternatives to reduce the use/ application of chemical nitrogen fertilizer along with improvement in crop production and decrease in greenhouse emissions in agricultural systems. Therefore, biofertilizers is of great importance in alleviating environmental pollution (Ibrahim *et al.*, 2009). Vessey (2003) estimated that the use of free-living nitrogen-fixing prokaryotes contribute to nitrogen input of soil ranges from 0 to 60 kg/ha/year. The microbial biomass is associated with rhizosphere which plays an important role in the crop growth and development through secretion of growth-promoting metabolites and nutrient supply. Thereby, increasing the health of roots during the growth stage by competing with root pathogens and increasing the absorption of nutrients and water (Daneshmand *et al.*, 2012). Therefore, for improvement in crop production and the soil fertility the plant growth-promoting bacteria and fungi utilization could be beneficial.

The improvement in sorghum green fodder yield (GFY) relies on the genetic variability and sorghum being hardy crop had noticed to have positive correlation with height (Mahajan *et al.,* 2011). However, there is inadequate knowledge on the genetics of green fodder yield (GFY) and dry fodder yield (DFY) and the traits associated with them, as a result desired improvement in fodder production has not been achieved so far. Therefore, present research work was carried out to study the effect of N-fixer (*Azotobacter* species) and P-solubilizers (*Sphingobacterium* sp., *Burkholderia* species and *Streptomyces badius*) inoculations and their interactions, in the presence of recommended dose of fertilizer (RDF) on single-cut forage sorghum.

MATERIALS AND METHODS

The field experiments was conducted at 2 locations of the Punjab Agricultural University, viz. Ludhiana (Forage and Research Farm) and Bathinda (Regional Research Station), during the rainy (*kharif*) seasons of 2016 and 2017. The soil of Ludhiana Research farm is loamy sand, having organic carbon content and *p*H of surface soil layer (0–15 cm) 0.38% and 8.30 respectively. The available nitrogen, phosphorus and potash in the surface layer were 171.5, 19.2 and 145.2 kg/ha respectively. The soil of the experimental site at Bathinda is also sandy loam, having alkaline *p*H (8.40) and low organic carbon (0.29%). The nutrient status of the soil during start of the experiment was low in available nitrogen (110 kg/ha), medium in available phosphorus (15.9 kg/ha) and high in available potassium (326.0 kg/ha). 'SL 44' sorghum single-cut variety was sown in the second week of July at both the locations in 2016 and 2017 in random block design with 3 replications, using seed rate of 25 kg/ha at 22 cm row spacing. The recommended dose of fertilizer (RDF) was 100 kg N and 20 kg P_2O_5/ha. Half of the nitrogen dose (50 kg/ha) and full phosphorus were drilled at the time of sowing and half nitrogen (50 kg/ha) was broadcast 1 month after sowing. The 10 ml of liquid biofertilizers, viz. *Azotobacter* species, *Sphingobacterium* species, *Burkholderia* species and *Streptomyces badius* species procured from Department of Microbiology (Punjab Agricultural University, Ludhiana) were used for seed treatment of sorghum before sowing and 9 treatments were used in the present study, viz. T_1, RDF (recommended dose of fertilizer); T_2, RDF + *Azotobacter* sp.; T_3, RDF + *Azotobacter* sp.+ *Sphingobacterium* sp.; T_4, RDF + *Azotobacter* sp.+ *Burkholderia* sp; T_5, RDF + *Azotobacter* sp.+ *Streptomyces badius*; T_6, 75% RDF + *Azotobacter* sp.; T_7, 75% RDF + *Azotobacter* sp.+ *Sphingobacterium* sp.; T_8, 75% RDF + *Azotobacter* sp.+ *Burkholderia* sp.; T_9, 75% RDF + *Azotobacter* sp.+ *Streptomyces badius*. Two irrigations were given at both locations in both the years during crop-growth period and the rainfall data of 2 locations for both the years are presented in Figs. 1 and 2. Atrataf 50 WP (atrazine) @ 1 kg/ha was applied as pre-emergence to control the weeds using 500 litres water with knap-sack sprayer using flat-fan nozzle. One hand-weeding was done at 35 days after planting.

The crop was harvested for green fodder and yield was recorded 70 days after sowing (DAS). The harvested green fodder was weighed plot-wise using hanging-scale electronic balance and was converted into tonnes/ha. Fresh weight (250 g) of plant samples was taken at the time of cutting and dried in the sun and then in the oven at 60 ± 2ºC to attain a constant weight. The dried samples were weighed and expressed as dry matter in t/ha. The dried samples were then finely meshed by grounding with Willy grinder and were used for estimation of quality parameters. Among quality traits, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), hydrocyanic acid (HCN) and *in-vitro* dry-matter digestibility (IVDMD) were estimated by Kjeldhal's method (AOAC, 1970), Goering and Van Soest (1970), Hogg and Ahlgren (1942) and Telly and Terry (1963) respectively. Yield and growth parameters were recorded to find correlation with fodder-quality traits. The data of 2 years were pooled and statistically analysed for interpretation of results. The data were analysed using the SAS software package. Comparisons of all means were done at the 5% probability level based on Duncan's method. The correlation matrix was prepared by using corrplot library in R studio.

RESULTS AND DISCUSSION

Yield and growth parameters

The pre-sowing treatment with biofertilizers resulted in had non-significant increase in yield and growth components of forage sorghum (Table 1). Among all the treatments, numerically higher non-significant pooled values for green-fodder yield (GFY) and dry-fodder yield (DFY), leaves/plant (LPP) and height at Ludhiana and Bathinda were recorded in 100% RDF + *Azotobacter* species + *Burkholderia* species (T_4) followed by 75% RDF + *Azotobacter* species + *Burkholderia* species (T_8) compared with the control. The increase in pooled values for GFY, DFY, LPP and height owing to T_4 treatment was 4.5, 6.1, 2.1 and 4.8%, respectively, over the control treatment (RDF no biofertilizer) (Table 1). Such slight improvement might be owing to production of growth-regulating components (IAA, GA etc.) by the inoculum microorganisms which resulted in better growth (Anand and Kamaraj, 2017). Mandal *et al*. (2000) also reported an increase in green- and dry-forage yield of oat through seed inoculation. El-Zieny *et al*. (2001) also reported that, bio-fertilizers such as *Azotobacter* and *Azospirillum* improved the plant growth and number of leaves/tiller. The observed non-significant but positive effect on plant height and LPP with microbial fertilizers could be attributed to increase in water and nutrient uptake, photosynthesis and also to the better development of roots along with increase in biological nitrogen fixation by liquid N-fixer biofertilizers promoting the accumulation of dry matter in plant's vegetative parts (Mirzaei *et al*., 2010). Further, Rekhi *et al.* (2000) and Mudenoor (2002) reported the role of the use of phosphate-solubilizing bacteria in making inorganic phosphate present in soil available to plant and also producing IAA phytohormones thereby, resulting in better yield owing increased nutrient absorption from soil.

In-vitro dry matter digestibility and crude protein

The forage digestibility is related to change in chemical composition and to some extent crude protein (Sher *et al.,* 2014). Therefore, forage containing high crude protein content is considered of good quality. Rahmani *et al.* (2008) reported that, nitrogen is the most important element in protein synthesis and its increase in optimum conditions increases the amount of protein. Crude protein plays an important role in fodder quality, as it is required for lactation, growth and reproduction of ruminants. The range of crude protein (CP) 7.1% to 8.8% and in-vitro dry matter digestibility (IVDMD) 60.7% to 68.5% at Ludhiana location was noticed to be more than that at the Bathinda location (Table 2). The increase in CP and IVDMD over

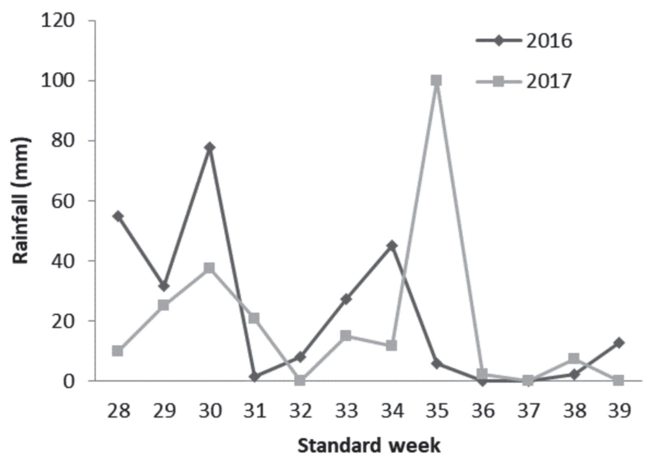

Fig. 1. Rainfall data during crop season 2016 and 2017 at Ludhiana, Punjab

Table 1. Effect of various liquid biofertilizers on forage sorghum growth parameters and yield at Ludhiana and Bathinda in Punjab

Treatment	Green fodder yield (t/ha)			Dry fodder yield (t/ha)			Leaves/plant (no.)			Height (cm)		
	L	B	POOL	L	B	POOL	L	B	POOL	L	B	POOL
T_1	54.6	42.1	48.3	13.6	10.0	11.8	12.2	11.1	11.62	163.3	153.8	158.55
T_2	56.7	42.4	49.5	14.1	10.2	12.2	12.3	11.2	11.75	165.7	155.8	160.73
T_3	57.2	42.5	49.8	14.5	10.3	12.4	12.3	11.1	11.71	168.3	159.8	164.07
T_4	58.0	43.0	50.5	14.6	10.5	12.5	12.4	11.3	11.86	171.0	161.2	166.11
T_5	57.1	42.2	49.7	14.4	10.1	12.2	12.4	11.3	11.82	167.7	155.7	161.73
T_6	56.9	42.0	49.4	14.1	10.1	12.1	12.2	11.1	11.64	167.3	154.9	161.12
T_7	57.1	42.1	49.6	14.4	10.1	12.3	12.3	11.1	11.69	166.3	158.1	162.23
T_8	57.9	42.7	50.3	14.5	10.3	12.4	12.4	11.3	11.80	169.2	160.8	165.01
T_9	56.5	41.9	49.2	14.3	9.8	12.0	12.3	11.2	11.72	166.3	154.7	160.53
SEm±	0.3	0.1	0.2	0.1	0.1	0.1	0.03	0.03	0.03	0.73	0.94	0.80
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

L, Ludhiana; B, Bathinda; POOL, pooled mean of 2 locations; T_1, recommended dose of fertilizer (RDF); T_2, RDF + *Azotobacter* sp.; T_3, RDF + *Azotobacter* sp. + *Sphingobacterium* sp.; T_4, RDF + *Azotobacter* sp.+ *Burkholderia* sp.; T_5, RDF + *Azotobacter* sp. + *Streptomyces badius* sp.; T_6, 75% RDF + *Azotobacter* sp.; T_7, 75% RDF + *Azotobacter* sp.+ *Sphingobacterium* sp.; T_8, 75% RDF + *Azotobacter* sp.+ *Burkholderia* sp.; T_9, 75% RDF + *Azotobacter* sp.+ *Streptomyces badius* the control from the 2 locations pooled mean was 21.5% and 16.8%, respectively, in RDF + *Azotobacter* sp. + *Burkholderia* species. Similar findings were reported by Haider (2008) that there was 7% increase in protein yield in forage oat with seed inoculation of *Azotobacter* over uninoculated (control).

Neutral detergent fibre and acid detergent fibre

The neutral detergent fiber (NDF-represents total cell-wall constituents including hemicelluloses) and acid detergent fibre (ADF represents cellulose and lignin) are used as standard fibre analysis testing technique for assessing fodder quality. The ADF is often used to calculate digestibility and NDF is used to predict intake potential. Therefore, lower value of ADF and NDF that is required for quality fodder was observed in sorghum fodder at Ludhiana than at Bathinda (Table 2). The treatment RDF + *Azotobacter* species + *Streptomyces badius* species (T_5) at Ludhiana and 75% RDF + *Azotobacter* species + *Burkholderia* species (T_8) at Bathinda showed lower ADF and NDF content followed by RDF + *Azotobacter* species+ *Burkholderia* species (T_4). The pooled mean of 2 locations revealed the highest and lower ADF content of 46.06% and 40.40% in T_1 and T_4 treatments, respectively (Table 2). Similarly, the treatments T_1 and T_4 showed higher (62.49%) and lower (53.53%) NDF content, respectively. Om Singh *et al*. (2018) found that, the crude fibre (CF) content was significantly influenced due to bio-fertilizer treatments. Maximum CF content (26.6% and 25.5%) were recorded under no bio-fertilizers treatment and the lowest CF (24.7% and 25.2%) was recorded with combination of *Azotobacter* and PSB application treatment, indicating better quality of fodder. This might be owing to the fact that the nitrogen uptake, which is the constituent of amino acids and protein, increased with increase in nitrogen fixation by the use of N-fixer microbial strain and thereby, decreased the pectin, cellulose and hemicellulose content–the major constituents of fibre. The moderate levels of NDF and ADF are responsible for generally high fodder IVDMD (Njidda, 2014). Kaur and Goyal (2017) reported that, increased levels of nitrogen in fodder oats increases the IVDMD. Hence, in the present study, application N-fixer biofertilizer inoculant increased the nitrogen levels which is the constituent of amino acids and protein and decreased the cellulose and hemicellulose content which are major constituents of fibre and thereby, increasing IVDMD. Lower crude fibres ADF and NDF and higher IVDMD indicating more palatability and digestibility of fodder sorghum as a result of biofertilizer treatment along with RDF.

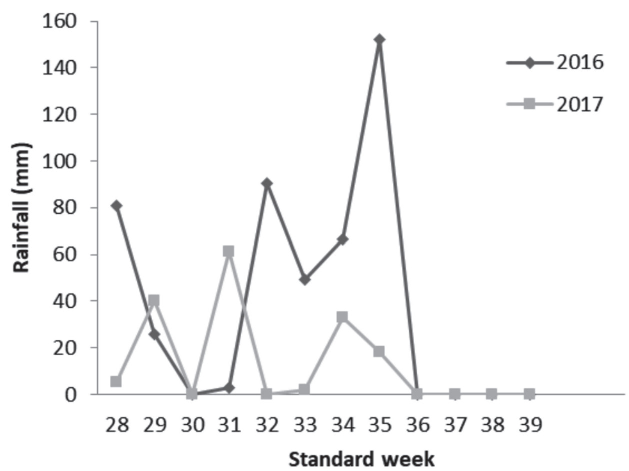

Fig. 2. Rainfall data during crop season 2016 and 2017 at Bathinda, Punjab

Table 2. Effect of various liquid biofertilizers on forage sorghum quality attributes at Ludhiana and Bathinda, Punjab

Treatment	Crude protein (%)			Acid detergent fibre (%)			Neutral detergent fibre (%)			*In-vitro* dry-matter digestibility (%)			Hydrocyanic acid (ppm)		
	L	B	POOL	L	B	POOL	L	B	POOL	L	B	POOL	L	B	POOL
T_1	7.1	6.5	6.75	45.5	46.6	46.06	65.1	59.9	62.49	60.7	45.0	52.83	86.4	86.7	86.6
T_2	7.8	6.9	7.34	41.9	43.6	42.73	61.5	58.7	60.10	64.1	47.2	55.65	80.4	80.0	80.2
T_3	7.6	6.8	7.16	41.1	41.4	41.23	54.9	56.2	55.56	62.9	50.7	56.82	69.5	77.6	73.6
T_4	8.8	7.6	8.20	39.9	40.9	40.40	53.0	54.1	53.53	68.5	55.0	61.72	64.7	66.1	65.4
T_5	8.5	6.6	7.50	39.7	43.6	41.67	51.5	58.9	55.21	65.4	54.3	59.89	80.2	78.5	79.4
T_6	7.3	6.7	6.98	42.7	46.1	44.38	54.0	53.5	53.75	65.5	51.9	58.70	79.5	78.3	78.9
T_7	7.3	6.4	6.86	42.3	44.3	43.33	60.5	53.3	56.92	63.5	51.6	57.58	67.2	68.5	67.9
T_8	7.2	6.6	6.90	41.7	40.1	40.88	56.3	53.2	54.73	63.9	53.7	58.80	59.6	60.3	60.0
T_9	7.2	5.9	6.54	42.8	41.8	42.27	57.1	53.7	55.39	63.0	47.5	55.25	77.7	75.5	76.6
SEm±	0.20	0.15	0.17	0.58	0.76	0.61	1.48	0.92	1.00	0.72	1.17	0.89	2.03	2.71	2.80
CD (P=0.05)	0.60	0.32	0.33	1.26	1.64	1.00	1.90	3.09	1.74	2.20	1.96	1.41	2.97	3.70	2.87

L, Ludhiana; B, Bathinda; POOL, pooled mean of 2 locations; T_1, recommended dose of fertilizer (RDF); T_2, (RDF) + *Azotobacter* sp.; T_3, RDF + *Azotobacter* sp. + *Sphingobacterium* sp.; T_4, RDF + *Azotobacter* sp.+ *Burkholderia* sp.; T_5, RDF + *Azotobacter* sp. + *Streptomyces badius* sp.; T_6, 75% RDF + *Azotobacter* sp.; T_7, 75% RDF + *Azotobacter* sp.+ *Sphingobacterium* sp.; T_8, 75% RDF + *Azotobacter* sp.+ *Burkholderia* sp.; T_9, 75% RDF + *Azotobacter* sp.+ *Streptomyces badius*

Hydrocyanic acid

Fodder sorghum contains an anti-quality agent called hydrocyanic acid (HCN). Cyanogenic potential of sorghum plant is a major limitation for its utilization as fodder. The safe threshold limit for livestock feeding is 200 ppm (on dry-weight basis) and 500 ppm (on fresh-weight basis) for HCN content in fodder sorghum. At both the locations, significantly low HCN content was seen in T_8 (75% RDF + *Azotobacter* species + *Burkholderia* species) followed by T_4 (RDF + *Azotobacter* species + *Burkholderia* species) compared with the other treatments and control (Table 2). This might be due to greater mobilization of nitrogen in formation of protein than in HCN formation. It has been reported that, the HCN proportion lowers as the height of the plant increases due to which it is harmful for the livestock at initial stages because of more cyanide concentration and toxicity decreases with maturity of plant (Pistoia *et al.,* 2003). Tariq *et al.* (2012) depicted strong negative genotypic and phenotypic correlations between total HCN content and number of tillers/plant, stem thickness, fresh weight/plant, dry weight/plant and green fodder yield.

CORRELATION

The results pertaining to correlations among various forage yield, yield related parameters and quality components are presented in Fig. 3. In the present study, there exist significant inter-relationship between the yield and quality traits. The results support the findings of Turk *et al.* (2015). Under all microbial treatments, there is a significant correlation of GFY with other forage yield parameters, i.e. plant height (0.95) and LPP (0.80). Tariq *et al*. (2012) and Amare *et al.* (2015) also reported significant positive correlation of GFY with other forage-yield parameters. From Fig. 3 it is interpreted that DFY exhibited the highest significant correlation coefficient of 1.00 with the GFY, followed by IVDMD (0.93) and then CP (0.71). Further the results of correlation indicated that the plant height should be given due importance, as it showed significant correlation of around 0.94 with dry-fodder yield. The GFY and DFY also showed positive significant correlation with CP

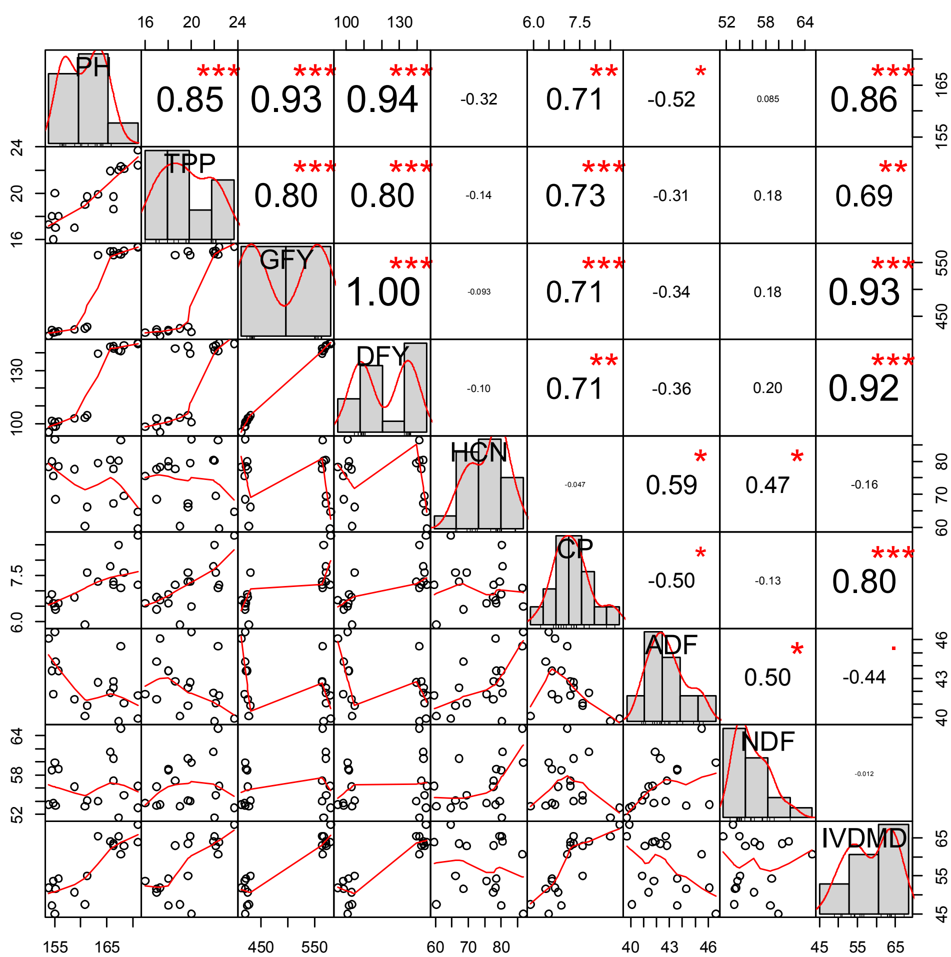

Fig. 3. The correlation between yield, yield components and quality of forage sorghum as affected by various liquid biofertilizer treatments (PH, Plant Height; LPP, Leaves Per Plant; GFY, Green Fodder Yield; DFY, Dry Fodder Yield; HCN, Hydrocyanic Acid; CP, Crude Protein; ADF, Acid Detergent Fibre; NDF, Neutral Detergent Fibre; IVDMD, *In-vitro* Dry-Matter Digestibility)

and IVDMD. Similar results were reported by Anup and Vijaykumar (2000). The GFY showed positive significant correlation with all fodder-quality traits (Fig. 3). Therefore, the increase in GFY will result in increase in quality of forage sorghum. The important quality parameters CP and IVDMD exhibited strong positive correlation of 0.80. On the other hand, HCN revealed significant negative relation with CP (–0.05) and IVDMD (–0.16). All the yield and yield-related parameters showed strong negative correlation with HCN and ADF. The HCN and ADF are the 2 negative fodder-quality traits and their presence in fodder reduces its acceptance for feeding livestock.

The correlation between ADF and NDF was noticed to be significant and positive (0.50) and this might be due to the fact the lignin and cellulose components of ADF are also the components of NDF. However, ADF and NDF had negative correlation of –0.50 and –0.13, respectively, with CP indicating that the higher CP would indicate lower fibre content in fodder crops and could be taken as one of the selection criteria. The use of liquid biofertilizers resulted in increase in CP and to some extent lowered the ADF and NDF content and thereby, proving their beneficial role in improving sorghum fodder yield, growth and quality.

The dual inoculation, i.e. *Azotobacter* species + *Burkholderia* species, along with RDF recorded higher fodder quality with improved fodder yield followed by same dual inoculation of biofertilizers with 75% RDF. It could be concluded from the present study that, inoculated N-fixer and P-solubilizers microbial stains might have a synergetic effect and might play a significant role in enhancing the productivity/unit area which is need of hour due to burgeoning pressure on natural resources. Furthermore, biofertilizers resulted in sorghum fodder that possessed the characteristics which are required for nutritious fodder.

REFERENCES

Amare, K., Zeleke, H. and Bultosa, G. 2015. Variability for yield, yield related traits and association among traits of sorghum [*Sorghum bicolor* (L.) Moench] varieties in Wollo, Ethiopia. *Journal of Plant Breeding and Crop Science* **7**: 125–133.

Anand, S. and Kamaraj, A. 2017. Influence of pre-sowing biofertilizers seed treatment on growth and yield parameters in rice (*Oryza sativa* L.). *Plant Archives* **17**: 1,377–1,380.

Anup, K.G. and Vijaykumar, S. 2000. Genetic variability and character association analysis in Sudan grass [*Sorghum sudanense* (Piper) Stapf]. *Karnataka Journal of Agricultural Science* **47**: 191–196.

A.O.A.C. 1990. *Official Methods of Analysis of the Association of the Official Agricultural Chemists*. Association of the Official Agricultural Chemists, Washington DC, USA.

Crawford, S.A., Shroff, J.C. and Pargi, S.B. 2018. Effect of nitrogen levels and cutting management on growth and yield of multicut forage sorghum [*Sorghum bicolor* (L.) Moench] variety Cofs-29. *International Journal of Agriculture Sciences* **14**: 118–122.

Daneshmand, N.G., Bakhshandeh, A. and Rostami, M.R. 2012. Biofertilizer affects yield and yield components of wheat. *International Journal of Agriculture* **2**: 699–704.

El-Zieny, O.A.H., El-Behari, U.A. and Zaky, M.H. 2001. Influence of biofertilizer on growth, yield and fruit quality of tomato grown under plastic house. *Journal of Agricultural Sciences* **26**: 1,749–1,763.

Georing, H.K. and Van Soest, P.J. 1970. *Forage Fibre Analysis*, *Apparatus reagents, procedures and some application*. Agriculture Handbook No. 379, Washington DC, USA

Haider, G. 2008. Effect of different sowing techniques on growth, forage yield and quality of four oat (*Avena sativa* L.) cultivars. *Pakistan Journal of Agricultural Sciences* **9**: 123–128.

Hogg, P.G. and Ahlgreen, H.L. 1942. A rapid method for determining hydrocyanic acid content of single plant of Sudan grass. *Journal of American Society of Agronomy* **34**: 199–200.

Ibrahim, Hoda I.M., Kandil, B.A.A. and Hamed, N.M. 2009. Influence of mineral and biofertilizer on forage yield and quality traits of teosinte. *Journal of Agricultural Sciences of Mansoura University* **34**: 6,515–6,530.

Kachroo, D. and Razdan, R. 2006. Growth, nutrient uptake and yield of wheat (*Triticum aestivum*) as influenced by biofertilizers and nitrogen. *Indian Journal of Agronomy* **51**: 37–39.

Kaur, G. and Goyal, M. 2017. Effect of growth stages and fertility levels on growth, yield and quality of fodder oats (*Avena sativa* L.). *Journal of Applied and Natural Sciences* **9**: 1,287–1,296.

Mahajan, R.C., Wadikar, P.B., Pole, S.P. and Dhuppe, M.V. 2011. Variability, correlation and path analysis studies in sorghum. *Research Journal of Agricultural Sciences* **2**: 101–103.

Mandal, S.R., Mukherjee, A.K. and Patra, B.C. 2000. Effect of biofertilizer (*Azotobacter*) inoculation on forage yield and quality of oat. *Indian Journal of Agricultural Sciences* **4**: 524–527.

Manjunath, S.B., Angadi, V.V. and Thimmegowda, P. 2013. Fodder yield and quality of multicut sorghum (CoFS-29) as influenced by row spacing and nitrogen levels. *Research Journal of Agricultural Sciences* **4**: 280–282.

Mirzaei, A., Vazan, S. and Naseri, R. 2010. Response of yield components of safflower (*Carthamus tinctorius* L.) to seed incolution with *Azotobacter* and *Azosprilium* and different nitrogen levels under dry land condition. *World Applied Science Journal* **11**: 1,287–1,291.

Mudenoor, M.G. 2002. Effect of micronutrient supplemented *Azospirillum* biofertilizers on maize (*Zea mays* L.). M.Sc. (Agriculture) Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Njidda, A.A. 2014. Determining dry matter degradability of some semi-arid browse species of north- eastern Nigeria using the *in-vitro* technique. *Nigerian Journal of Basic and Applied Science* **18**: 160–167.

Om Singh, Chaturvedi, V.B., Verma, M.R. and Singh, H.C. 2018. Effect of integrated nutrient management on hybrid napier production under irrigated conditions. *International Journal of Current Microbiology and Applied Science* **7**: 2,731–2,737.

Pindi, P.K. 2012. Liquid microbial consortium–a potential tool for sustainable soil health. *Journal of Biofertilizer and*

Biopesticide **3**: 1–9.

Pistoia, A., Poli, P., Casarosa, L., Berni, P. and Feruzzi, G. 2003. Sorghum utilization for summer grazing: *dhurrin* problem. *Italian Journal of Animal Sciences* **2**: 207–209.

Rahmani, N., Valadbighi, S.A., Daneshian, J. and Bidgholi, V.M. 2008. Effect of different levels of drought stress and nitrogen on oil yield in evergreen herb (*Calendula officinalis* L.). *Journal of Research on Aromatic Plant Iran* **24**: 101–108.

Rekhi, R.S., Benbi, D.K. and Singh, B. 2000. Effect of fertilizers and organic manure on crop yields and soil properties in rice-wheat cropping system. (In) Abrol, I.P., Bronson, K.F., Duxbury, J.M. and Gupta, R.K. (Eds.), Long-term Soil Fertility Experiments in Rice–Wheat Cropping Systems. Rice Wheat Consortium Paper Series 6. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India, 1–6.

Saleem, M., Zamir, M.S.I., Haq, I., Irshad, M.Z., Khan, M.K., Asim, M., Zaman, Q., Ali, I., Khan, A. and Rehman, S. 2015. Yield and quality of forage oat (*Avena sativa* L.) cultivars as affected by seed inoculation with nitrogenous strains. *American Journal of Plant Sciences* **6**: 3,251–3,259.

Sher, A., Ansar, M., Manaf, A., Qayyum, A., Saeed, M.F. and Irfan, M. 2014. Hydrocyanic acid and sugar content dynamics under nitrogen and sulphur application to forage sorghum cultivars. *Turkish Journal of Field Crops* **19**: 46–52.

Tariq, A.S., Akram, Z., Shabbir, G., Gulfraz, M., Khan, K.S., Iqbal, M.S. and Mahmood, T. 2012. Character association and inheritance studies of different sorghum genotypes for fodder yield and quality under irrigated and rainfed conditions. *African Journal of Biotechnology* **11**: 9,189–9,195.

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

Turk, M., Albayrak, S. and Bozkurt, Y. 2015. Determination of the relationships between crude protein content and other forage quality parameters in grazed and nongrazed pastures by correlation and path analysis. *YYU Journal of Agriculture Science* **25**: 207–213.

Vessey, J.K. 2003. Plant growth promoting rhizobacteria as biofertilizers. *Plant Soil* **255**: 571–586.

Yadav, P.C., Sadhu, A.C. and Swarnkar, P. K. 2007.Yield and quality of multi-cut forage sorghum (*Sorghum sudanense*) as influenced by integrated nutrient management. *Indian Journal of Agronomy* **52**: 330–334.

Indian Journal of Agronomy **65** (1): 107–110 (March 2020)

Research Communication

Nutrient management in wheat (*Triticum aestivum*) for improving grain yield, nutrient-use efficiency and profitability

TANMOY PAIK[1], YASHWANT SINGH[2] AND RAHUL SADHUKHAN[3]

Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005

Received: March 2019; Revised accepted: March 2020

ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2016–17 at Agriculture Farm, Banaras Hindu University, Varanasi, Uttar Pradesh, to study the effect of nutrient management (nitrogen, phosphorus and potassium levels) on growth and yield of wheat (*Triticum aestivum* L.). The experiment was laid out in a randomized complete block design with 3 replications and 8 treatments [control, recommended dose of fertilizers (RDF: 150 N + 60 P_2O_5 + 40 K_2O kg/ha), 150% RDF, 150% PK, 150% NK, 150% NP, GreenSeeker-guided nitrogen application at the 2nd irrigation (P_2O_5 and K_2O as RDF dose) and RDF + 10 t FYM/ha]. Various yield attributes of wheat showed significant variation under different levels of NPK and GreenSeeker-based precision nutrient management. It was observed that, an application of 150% of recommended dose of fertilizer (225 N + 90 P_2O_5 + 60 K_2O kg/ha) resulted in the highest yield and net returns. However, GreenSeeker-guided nitrogen application saved fertilizer nitrogen (32 kg/ha) without significant reduction in yield than blanket recommendation of recommended dose of fertilizer in 'HD 2967' wheat. In terms of grain-yield increment, it was found that there was 10.6% increase of grain yield by 150% NPK compared to RDF and 7.8% yield increase over 150% NP. In case of economic returns, 12.95% profit increment was achieved by 150% RDF over RDF. So, 150% NPK application to wheat crop at Varanasi, Uttar Pradesh, is fruitful for farmers point of view for improvement of low N-use efficiency.

Keywords: GreenSeeker, optical sensor, precision nitrogen management, NDVI, Level of nutrients

Wheat is the most important cereal crop in the world, widely cultivated around 220 million ha to ensure food security in 94 countries. Area of wheat in north-eastern plain zone of India is 10.5 million ha which contributes 27% of the total area of wheat. The production of wheat from this region contributes 24% of total wheat production in India (Directorate of Wheat Annual Report, 2012–13). The recommended rate of N-P_2O_5-K_2O under irrigated timely sown condition in north-eastern plain zone is 150–60–40 kg/ha respectively. Nitrogen is the nutrient that most often limits crop production (Pathak *et al*., 2003). Worldwide nitrogen-use efficiency for cereal grains and row crops estimated at only 33% (Raun and Johnson, 1999). Unaccounted 67% represents a loss of fertilizer nitrogen. Present N : P : K ratio followed in India is 6.7 : 2.7 : 1, where the ideal recommendation is 4 : 2 : 1 (Sadhukhan, 2018). Indian soil is mostly deficient in nitrogen by 0.02–2.2%. Top-dressing of nitrogen by split doses is needed during the period of higher requirement (Dobermann and Fairhaust, 2000). Efficient use of N fertilizer is restricted due to large field-to-field variability, when broad-based general fertilizer recommendations are used (Adhikari *et al*., 1999; Dobermann *et al*., 2003). Farmers generally use leaf-colour chart as an indication of nitrogen-application requirement. Optical sensors were used in calculating the fertilizer-nitrogen requirement in wheat (Singh *et al.,* 2011) and in cereal (Raun *et al.,* 2002). Farmers can handle it easily, fast and real-time data can be taken and it can be used as a complementary decision-making tool. GreenSeeker may offer a more efficient and precise way to manage crop nitrogen input and estimates the right amount of N at the critical stages of crop-growth (Sapkota *et al.,* 2014). It is an integrated optical sensing, variable rate application and mapping system that measures nitrogen requirements of a crop. Crop-yield potential is identified using a vegetative index known as

Based on a part of M.Sc. thesis of the first author submitted to the Banaras Hindu University, Varanasi, Uttar Pradesh in 2018 (Unpublished).

[1]**Corresponding author's Email**: tanmoypaik1993@gmail.com
[1]Ph.D Scholar, (Agronomy), BCKV, Kalyani, West Bengal 741 235, [2]Professor (Agronomy), Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005; [3]Ph.D. Scholar (Agronomy), ICAR-Indian Agricultural Research Institute, New Delhi 110 012

normalized difference vegetation index (NDVI) and an environmental factor namely growing degree-days (GDD) (Rouse, 1974). This technology was developed at the Oklahoma State University, USA, and licensed to N Tech Industries in 2001. Presently, most of the investigation and crop-nutrient research limited to conventional approaches only. Need-based precision-nutrient management in the crop field will greatly increase fertilizer-use efficiency and will save costly fertilizers. So, precision-nutrient management should be done with due to objective (i) to study the effect of GreenSeeker-based N management on wheat crop and (ii) assess the effect of N, P and K on growth and yield of wheat.

The field experiment was conducted during the winter (*rabi*) season of 2016–17 at Agriculture Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25°18' N, 83°03' E and 128.9 mean sea-level), situated in the centre of north Gangetic alluvial plains. The experimental site has semi-arid to hub-humid type of climate with moisture deficit index between 20 and 40%. The average annual rainfall at Varanasi is 1,100 mm and about 88% of it is received during June–September. The soil of experimental field was sandy clay loam, moderately fertile, low in available organic carbon (0.38%) and nitrogen (204.4 kg/ha), medium in phosphorus (21.2 kg/ha) and potassium (226 kg/ha) and having neutral soil reaction (*p*H 7.32) and electrical conductivity (0.25 dS/m). The experiment was laid out in randomized complete block design with 8 treatments in 3 replications. The treatments were: T_1, recommended dose of fertilizer; T_2, (150-60-40 kg/ha N-P_2O_5-K_2O; T_2); T_3, 150% RDF; T_4, 150% PK; T_5, 150% NK; T_6, 150% NP; T_7, GreenSeeker guided nitrogen application; and T_8, RDF + 10 t FYM/ha. The wheat variety 'HD 2967' was sown in a well- prepared soil with a row-to-row spacing of 20 cm and in solid line at a seed rate of 100 kg/ha. Sources of fertilizers were urea (46% N), diammonium phosphate (18% N and 46% P_2O_5) and muriate of potash (60% K_2O). Nitrogen, phosphorus and potash were applied as per the treatment. Nitrogen was applied in 3 equal splits–one-third of the total N as applied at basal next at 1st irrigation and finally rest at 2nd irrigation. Particularly for treatment GreenSeeker-guided nitrogen dose was given at the 2nd irrigation was calculated from NDVI readings. Various observations pertaining to yield attributes and yield of wheat were recorded and their significance was tested by the variance ratio (~F-value) at 5% level (Gomez and Gomez, 1984). Economics was calculated as per the prevailing market prices of the inputs and produce during the year of the experimentation.

Application of 150% RDF resulted in the highest number of ears/m^2, grains/ear and test weight over the rest of the treatments of wheat. GreenSeeker-guided nitrogen application was found at par with RDF in respect to grain yield of wheat. The control showed lesser number of ears/m^2, grain/ear, earhead length and test weight which were at par with 150% PK treatment. All the treatments except 150% PK showed significantly higher grain and straw yield as compared to the control treatment. Recommended dose of fertilizer provided at par yield with GreenSeeker-guided nitrogen application (Table 1). The increase in number of grains might be owing to better assimilation of carbohydrates in ears. Mohanty *et al.* (2015) at New Delhi, opined to increase nitrogen dose as RDF. Maximum grain and straw yields were observed in treatment 150% RDF (5.93 t/ha and 9.18 t/ha respectively). Recommended dose of fertilizer showed at par yield result with GreenSeeke guided-nitrogen application (5.21 and 7.38 t/ha respectively). Minimum grain and straw yield were observed in the control treatment which was at par with 150% PK. All the treatments except 150% PK showed significantly higher grain and straw yields over the control treatment. Similar result was reported by Singh (2014). He observed GreenSeeker-based fertilizer N management always resulted substantial savings in as compared to prevalent blanket recommendations but with no reduction in yield. Adequate nitrogen supply during reproductive stage (one-fourth of total nitrogen dose) as probably the reason for enhancing the yield parameters and ultimately yields. Lower value of yield in control and 150% PK treatments were mainly due to inadequate nitrogen supply to meet the crop requirement. As per the rate of the nutrient application, the source of fertilizers, blanket and GreenSeeker-guided nitrogen application, the cost of cultivation varied greatly under different treatments. The cost of cultivation was the maximum in 150% RDF treatment (34.07×10^3 ₹/ha). Net returns (77.94×10^3₹/ha) and benefit: cost ratio (2.29) were also significantly higher in 150% NPK compared to rest of the treatments. This may be owing to higher grain and straw yields in this treatment. The GreenSeeker-guided nitrogen application showed an almost equal cost of cultivation, gross return, net returns and benefit: cost ratio with RDF treatment. This may be owing to significantly similar grain and straw yields and amount of nitrogen saved using GreenSeeker. The 150% PK treatment showed the minimum net return, benefit: cost ratio and even the cost of cultivation was low as compared to other treatments under study (Table 1). This may be due to lower grain and straw yields and higher cost of cultivation in term of P and K fertilizer cost. Due to lower dose of nitrogen, yield was poor, thus higher quantity of P and K have shown no beneficial effect. Application of 150% NPK improved the agronomic efficiency considerably but more prominent agronomic efficiency was found in GreenSeeker-guided N application + PK as recommended dose (Table 1). Apparent