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Response of sorghum (*Sorghum bicolor*) cultivars to nitrogen in non-traditional areas of Bihar

RAKESH KUMAR[1], GOVIND MAKARANA[1], J S MISHRA[2]* and B P BHATT[3]

ICAR-Research Complex for Eastern Region, Patna, Bihar 800 014, India

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ABSTRACT

A field experiment was conducted at the research farm of ICAR-Research Complex for Eastern Region, Patna, Bihar during summer season of 2017 and 2018 to assess the production potential of grain sorghum (*Sorghum bicolor* L. Moench) cultivars as influenced by nitrogen levels. Treatments consisting 4 nitrogen levels (0, 40, 80 and 120 kg/ha) as main-plot and 09 sorghum cultivars including 5 hybrids (CSH 13, CSH 14, CSH 16, CSH 25 and CSH 30) and 04 varieties (CSV 15, CSV 20, CSV 23 and CSV 27) as sub-plot, were replicated thrice in a split-plot design. Results revealed that increasing levels of nitrogen from 40–120 kg/ha brought significant improvement in yield attributes and yield over control. Application of 120 kg N/ha produced a maximum grain yield (4.82 t/ha) and net returns (₹79.5×10^3 /ha). Amidst cultivars, CSH 30 recorded significantly higher grain yield (4.92 t/ha), net returns (₹82.3×10^3/ha), benefit-cost ratio (3.34) and economic efficiency (₹843 ha/day). Hence, sorghum cultivar CSH 30 grown along with 120 kg N/ha was proved significantly better in terms of crop productivity and profitability in summer season, and may be adapted as choice of viable alternative in non-traditional area of eastern India.

Keywords: Grain sorghum, Nitrogen levels, Non-traditional area, Productivity, Profitability

Sorghum (*Sorghum bicolor* L. Moench) is a fast-growing crop, well adapted to high temperature and water-stress conditions compared to other cereals (Prakash *et al.* 2017). In India, sorghum is grown during rainy (*kharif*) season as well as post-rainy seasons. There is a large time gap (~70–90 days) existing between the harvesting of wheat and transplanting of rice particularly in Indo-Gangetic Plains (IGPs). Thus, a major portion of IGP in India remains fallow during this gap period, which can be utilized by any short duration crop (Kumar *et al.* 2020). Being a C_4 crop, sorghum utilizes solar radiation more efficiently, thus can be fitted in cropping systems with limited irrigation facilities. Under the changing climate scenario, sorghum being a drought-hardy crop will play an important role in food, feed and fodder security of eastern India. It can be a potential alternative to summer mungbean, which suffers badly due to infestation of yellow mosaic virus (YMV). Cultivation of short-duration sorghum genotypes during summer has greater scope owing to congenial conditions, i.e. free from natural vagaries, incidence of the insect-pest and diseases. Besides the environment, genotypes and management factors play a crucial role in affecting production of sorghum. Among the agronomic management practices, nutrient management is utmost important, which helps to achieve an economically viable return. Nitrogen is an important plant nutrient for improving the crop productivity (Olugbemi 2017). Application of nitrogen in sorghum has resulted in variable responses due to differences in climate, soil and genotypic factors across seasons and locations (Bahar *et al.* 2018). Thus, the present study was conducted to explore the production potential of different sorghum cultivars with varying levels of nitrogen during summer season under irrigated agro-ecosystem of eastern India.

MATERIALS AND METHODS

The present study was carried out at the research farm of ICAR-Research Complex for Eastern Region, Patna, Bihar (25°30’ N, 85°15’ E, 52 m amsl) during summer seasons of 2017 and 2018. Initial status of soil (0–15 cm depth) of experimental field was clay loam (23.36% sand, 39.64% silt and 37% clay) in nature, low in organic carbon (0.47%) and nitrogen (213 kg N/ha), medium in available phosphorus (19.7 kg P/ha), high in available potassium (336 kg K/ha) and neutral in soil reaction (*p*H 7.43). Meteorological phenomenon occurring during study period (March–July of 2017 and 2018) are presented in Fig 1. The experiment was conducted in a split-plot design with three replications with 4 nitrogen (N) levels, viz. 0, 40, 80 and 120 kg N/ha considered as main-plot and 9

[1]ICAR-Research Complex for Eastern Region, Patna, Bihar; [2]ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh; [3]ICAR-KAB-II, New Delhi. *Corresponding author email: jsmishra31@gmail.com

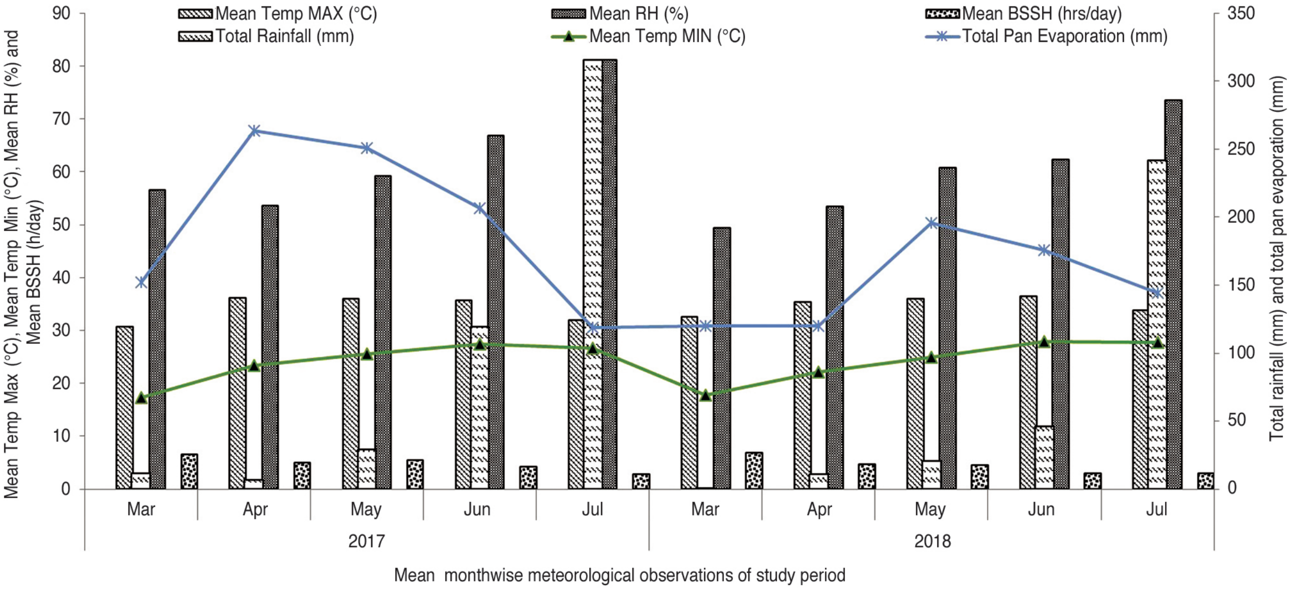

Fig 1 Mean weather attributes during cropping periods.

grain sorghum cultivars (including hybrids and varieties), viz. CSH 13, CSH 14, CSH 16, CSH 25, CSH 30, CSV 15, CSV 20, CSV 23 and CSV 27 were considered as sub-plot treatments. Recommended dose of phosphorus and potassium i.e. 40 kg each was applied in all treatments through di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively. Nitrogen was applied through urea after subtracting N amount supplied in the form of DAP. DAP/MOP was applied as basal whereas, nitrogen was applied in two equal splits, 50% as basal and remaining at 35 days after sowing (DAS). Net plot size was 5.0 × 4.0 m and crop was planted manually with spacing of 45 × 15 cm. Furadan 3 G @5 kg/ha was applied in furrows at 35 DAS to control shoot-fly [*Atherigona soccata* (Rondani)]. To control the initial weed flushes, atrazine @0.50 kg/ha was applied as pre-emergence with 500 l/ha water with the help of knapsack sprayer fitted with flat-fan nozzle. Hand-hoeing was done at 25 DAS and intra-row weeds were removed by hand-weeding simultaneously. To supplement the total rainfall, three irrigations were also given during cropping period at critical stages. Five randomly selected plants from each plot were taken for yield attributes i.e. panicle length, panicle weight, grains/panicle (no.) and 1000-grain weight at crop harvest. The number of panicles, grain and straw yields were recorded from randomly selected 1 m^2 area from each plot. Gross returns were calculated on basis of the minimum support price (MSP) as declared by Government of India of grain sorghum of respective years. Net returns were calculated as a difference between gross returns and total cost of cultivation. Benefit:cost was worked out by dividing gross returns with total cost of cultivation. Dry-matter and unit area efficiency were computed by the following formula as suggested by Kumar *et al.* (2017).

Dry matter efficiency = (seed yield/total dry matter production) × (100/duration of crop)

Unit area efficiency = (seed yield/land area) × (1/duration of crop)

Statistical analysis: All the recorded data were analyzed with help of analysis of variance (ANOVA) technique using SAS 9.4 (Indian NARS Statistical Computing Portal). The least significant difference test (LSD) was used for comparison of treatment means (DMRT) at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Phenological attributes: Different nitrogen levels did not show marked variations in days to 50% flowering (DFF) as well as in days to maturity (DTM), whereas different cultivars differed significantly for these phonology attributes. Though, application of 120 kg N/ha showed the minimum DFF and DTM (64.6 and 95.4) (Table 1). Among the cultivars, CSV 20 (59.7 days) was at par with CSV 23 (60.6 days), and had significantly shortest time for DFF, however, maximum period was taken by CSH 13 to attain days to 50% flowering (72.4 days). Sorghum variety CSV 15 recorded the shortest time to reach crop maturity (96.4 days) compared to CSV 27, CSV 25, CSH 16 and CSV 20, while CSV 27 took significantly maximum time to attain crop maturity (106.3 days). Mishra *et al.* (2017) also observed significant variations in phonology of sorghum cultivars.

Unit area and dry matter efficiency: Application of N @40, 80 and 120 kg/ha markedly enhanced unit area efficiency over control. Magnitude of enhancement in unit area efficiency due to application of 40, 80 and 120 kg N/ha was in the tune of 17.2, 41.4 and 75.9%, respectively compared to control (Table 1). Among the cultivars, the maximum unit area efficiency was recorded with CSH 30. The adequate supply of N resulted in optimum utilization of natural resources i.e. light, space, water and other nutrient thus might have resulted in higher root and shoot growth,

Table 1 Phenology and yield attributes of sorghum as influenced by different nitrogen levels and cultivars (pooled data of 2 years)

Treatment	Days to 50% flowering	Days to maturity (no.)	Panicle length (cm)	Panicle/m^2 (no.)	Panicle weight/ plant (g)	Grains/ panicle (no.)	1000-grain weight (g)	Unit area efficiency (kg/ha/day)	Dry matter efficiency (%/day)
Nitrogen level (kg/ha)									
0	68.3^{A}	102.4^{A}	35.0^{D}	15.7^{B}	93.6^{B}	2630^{D}	24.7^{D}	0.029^{D}	0.192^{A}
40	67.7^{A}	101.0^{A}	36.0^{C}	15.8^{B}	94.2^{B}	2700^{C}	25.4^{C}	0.034^{C}	0.178^{AB}
80	66.4^{A}	98.8^{A}	37.4^{B}	16.5^{A}	94.6^{B}	2762^{B}	26.1^{B}	0.041^{B}	0.176^{B}
120	64.6^{A}	95.4^{A}	39.7^{A}	16.6^{A}	96.7^{A}	2823^{A}	26.7^{A}	0.051^{A}	0.188^{AB}
Cultivar									
CSH 13	72.4^{A}	99.2^{BC}	37^{BC}	16.2^{CD}	114.4^{A}	3024^{B}	28.2^{B}	0.039^{BC}	0.178^{D}
CSH 14	69.7^{B}	97.3^{BC}	36.4^{DE}	17.3^{AB}	87.4^{E}	2600^{F}	26.7^{C}	0.041^{B}	0.182^{C}
CSH 16	69.6^{B}	100^{B}	36.9^{BC}	16.2^{CD}	109.5^{B}	2323^{H}	24.7^{G}	0.041^{B}	0.176^{DE}
CSH 25	67.7^{B}	99.6^{B}	37.3^{B}	16.2^{CD}	104.3^{C}	3061^{A}	28.6^{A}	0.041^{B}	0.182^{C}
CSH 30	69.4^{B}	98.3^{BC}	37^{BC}	17.5^{A}	83.5^{F}	2615^{E}	24.2^{H}	0.05^{A}	0.184^{C}
CSV 15	62.7^{C}	96.4^{C}	37.4^{B}	14.9^{E}	83.2	2739^{D}	25.4^{F}	0.034^{D}	0.193^{AB}
CSV 20	59.7^{D}	99.5^{B}	36^{E}	16.1^{D}	91.3^{D}	3018^{B}	25.6^{E}	0.037^{C}	0.194^{A}
CSV 23	60.6^{CD}	97.8^{BC}	38.3^{A}	16.7^{BC}	71.1^{G}	2828^{C}	26.3^{D}	0.031^{E}	0.19^{B}
CSV 27	68.8^{B}	106.3^{A}	36.6^{CD}	14.5^{E}	108.2^{B}	2350^{G}	21.5^{I}	0.033^{DE}	0.173^{E}

Different letters in a column are significantly different at $P<0.05$ according to Duncan's multiple range test.

photosynthetic area which had played an important role in raising biomass production consequently higher dry matter yield. Increased dry matter was associated with efficiencies with respective treatments. Dry matter efficiency also got influenced significantly by both imposed factors. Among cultivars, CSV 20 with a value of DME 0.194%/day was found at par with CSV 15 (0.193%/day) and observed significantly higher than rest cultivars. This might be due to more dry matter production (Kumar *et al.* 2017).

Yield attributes: In general, imposition of 40, 80 and 120 kg N/ha levels enhanced all yield attributes over control (Table 2). Magnitude of enhancement in panicle length due to application of 120 80 and 40 kg N/ha levels was in tune of 13.3, 6.8 and 2.8%, respectively over control. Among the cultivars, maximum and minimum panicle length was confirmed in CSV 23 and CSV 20 (38.3 and 36 cm). Application of 120 and 80 kg N/ha levels (16.6 and 16.5) had statistically similar panicle/m^2 and both were higher as compared to 40 kg N/ha and control (15.8 and 15.7), respectively. Sorghum hybrid CSH 30 recorded significantly higher panicle number (17.5) amongst all the tested cultivars. Significantly heavier panicle (96.7 g) was obtained in 120 kg N/ha compared to other levels (Table 1). Panicle weight remained unaffected due 80 and 40 kg N/ha levels (94.6 and 94.2 g, respectively) compared to control. Different cultivars had a pronounced effect on panicle weight and considerably the heaviest panicle was observed in CSH 13 (114.4 g). All the imposed N treatments i.e. 40, 80 and 120 kg/ha levels significantly increased the number of grains/ panicle of sorghum (Table 1). Application of 120 kg N/ha level registered significantly maximum number of grains/ panicle (2823). Among cultivars, CSH 25 (3061) followed by CSH 13 (3024) and CSV 20 (3018) expressed significantly higher number of grains/panicle compared to other cultivars. Application of nitrogen @40, 80 and 120 kg/ha caused a significant enhancement in 1000-grain weight of sorghum over control (Table 1). Among cultivars, significantly the maximum 1000-grain weight was noted in CSH 25 (28.6 g) and minimum with CSH 30 (24.2 g). Increased values of yield attributes with increased N level could be explained on the basis of improved availability of desired and required nutrients in crop root zone and increased photosynthetic and metabolic activity, resulting in improved partitioning of photosynthates into sinks, which might have reflected as in improvement in these attributes (Mishra *et al.* 2015).

Crop productivity: Varying levels of N and cultivars brought significant effects on crop productivity (Table 2). Application of 120 kg N/ha resulted in maximum grain yield (4.82 t/ha) as compared to remaining levels of N applied. Magnitude of increment in grain yield was due to practicing 40, 80 and 120 kg N/ha was in the tune of 18.2, 38.7 and 65.1%, respectively over control. Amidst the cultivars, CSH 30 proved significantly better in terms of grain yield (4.92 t/ha). Same cultivar and N level was noted higher for straw, biological and dry matter yield. Application of 120 kg N/ha showed the highest harvest index (HI) (29.2). Nitrogen levels of 40, 80 and 120 kg/ha caused 30.3, 63.3 and 90.2% enhancement in HI, respectively over control (0 kg N/ha; 15.3% HI). Among various cultivars, maximum HI (28.7%) was achieved in CSH 30 and minimum with CSV 23 (17.8%). Increased N application rate improved growth and yield attributes due to their beneficial effects on cell elongation and differentiation, formation of nucleotide and co-enzyme consequently increased operation of meristematic

Table 2 Yield and economics of sorghum as influenced by different nitrogen levels and cultivars (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Dry matter yield (t/ha)	Harvest index (%)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit :cost (B:C) ratio	Economic efficiency (₹/ha/day)
Nitrogen level (kg/ha)									
0	2.92^{D}	15.0^{D}	17.87^{D}	14.9^{D}	15.3^{D}	67.5^{D}	33.9^{D}	2.01^{D}	333^{D}
40	3.45^{C}	19.5^{C}	22.95^{C}	19.4^{C}	20^{C}	82.1^{C}	48.1^{C}	2.42^{C}	479^{C}
80	4.05^{B}	24.4^{B}	28.48^{B}	23.4^{B}	25.0^{B}	98.2^{B}	62.7^{B}	2.77^{B}	635^{B}
120	4.82^{A}	28.4^{A}	33.27^{A}	27.1^{A}	29.2^{A}	116.1^{A}	79.5^{A}	3.17^{A}	835^{A}
Cultivar									
CSH 13	3.87^{C}	22.1^{C}	26.0^{D}	22.1^{C}	22.7^{C}	92.3^{C}	57.4^{C}	2.63^{CD}	584^{C}
CSH 14	3.99^{BC}	23.0^{B}	27.0^{C}	22.7^{C}	23.6^{B}	95.4^{C}	60.5^{C}	2.71^{C}	629^{B}
CSH 16	4.13^{B}	23.9^{B}	28.0^{B}	23.5^{B}	24.5^{B}	98.79^{B}	63.9^{B}	2.82^{B}	643^{B}
CSH 25	4.11^{B}	23.7^{B}	27.8^{BC}	22.9^{BC}	24.3^{B}	98.3^{BC}	63.4^{BC}	2.81^{B}	639^{B}
CSH 30	4.92^{A}	28.0^{A}	32.9^{A}	27.5^{A}	28.7^{A}	117.3^{A}	82.4^{A}	3.34^{A}	843^{A}
CSV 15	3.21^{F}	18.5^{E}	21.7^{G}	17.5^{E}	18.9^{E}	76.7^{F}	41.8^{F}	2.18^{F}	442^{E}
CSV 20	3.65^{D}	20.6^{D}	24.2^{E}	19.3^{D}	21.1^{D}	86.7^{D}	51.8^{D}	2.47^{D}	525^{D}
CSV 23	2.99^{G}	17.4^{F}	20.4^{H}	16.2^{F}	17.8^{F}	71.7^{G}	36.8^{G}	2.03^{G}	385^{F}
CSV 27	3.44^{E}	19.4^{E}	22.8^{F}	19.0^{D}	19.9^{E}	81.7^{E}	46.8^{E}	2.32^{E}	447^{E}

Different letters in a column are significantly different at $P<0.05$ according to Duncan's multiple range test.

tissue and photosynthetic area. 1000-grain weight, yield and HI increased as amount of N fertilizer increased. This might be owing to the fact that nitrogen fertilizers will give a healthy, vigorous plant, and plant will be photo-synthetically more efficient. Inherent variations and vigour behavior led to varied values of growth attributes consequently yields of the crop (Kumar *et al.* 2015). Higher HI under CSH 30 showed that this genotype was more efficient in converting biological yield into economic yield. Our results are in close proximity with the earlier findings of Kumar *et al.* (2017).

Economics: Application of N @40, 80 and 120 kg/ha markedly enhanced gross returns, net returns, benefit-cost ratio and economic efficiency over control (Table 2). Maximum values of these traits were achieved in 120 kg N/ha. Magnitude of enhancement of nitrogen @40, 80 and 120 kg/ha in net returns was in tune of 42, 85 and 135%, respectively compared to control. CSH 30 recorded noticeably higher gross returns (₹117.3×10^3/ha), net return (₹82.3×10^3/ha), benefit:cost (B:C) ratio (3.34) and economic efficiency (₹843/ha/day) compared to rest of the cultivars. However, CSV 23 had significantly lower values of these attributes. Similar findings were reported by Kumar *et al.* (2017) and Mishra *et al.* (2017) in grain sorghum cultivars.

Based on the results it could be concluded that sorghum hybrid CSH 30 with 120 kg N/ha proved significantly better in productivity and profitability during summer season in non-traditional area of eastern India.

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