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Performance and nitrogen use efficiency of grain sorghum through method and time of nitrogen application under semi-arid environment

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Abstract
The present field investigation was carried out for three consecutive *kharif* season of 2015, 2016 and 2017 at research farm of Agricultural Research Sub Station Diggi, Tonk to improve nitrogen use efficiency through method and time of nitrogen application and performance of sorghum under semi arid environment of Rajasthan, India. The experiment was laid out in factorial randomized block design consisted of five nitrogen scheduling treatments *viz.* N1 (50+50), N2 (50+25+25), N3 (25+50+25), N4 (25+50+15+10), N5 (25+45+5+15+10), and two genotypes *viz* CSH-16 and CSV-20 and replicated thrice. The results revealed that the application of nitrogen with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage recorded significantly maximum plant height and dry matter accumulation of sorghum. The application of nitrogen with 25% N at sowing + 50% N at 30 DAS + 15% N at boot leaf stage+10% at Grain filling stage recorded minimum plant height and dry matter accumulation of sorghum. The significantly maximum number of grains/cob (3136.3) and test weight (28.0 g) were registered with application of nitrogen with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage. However, crop supplied nitrogen with the 50% N at sowing + 50% N at 30 DAS recorded statistically similar results for these yield attributes. The grain, stover and biological yields of sorghum due to different method and time of nitrogen application treatments were found statistically at par. The application of nitrogen with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage resulted in increased mean gross return (Rs. 89159). Among the method and time of nitrogen application treatments, the highest cost of cultivation (₹26301), gross returns (₹89159) net returns (₹62858) and B:C ratio (2.39) were recorded with application of nitrogen with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage. The experimental results supported the hypothesis that nitrogen use efficiency could be improved by method and time of nitrogen application. Proper method and time of nitrogen application have positive impact on growth, productivity and profitability of grain sorghum. Thus, it is concluded that improvement of nitrogen use efficiency through method and time of nitrogen application can be advocated as sustainable strategy for enhancing productivity and profitability of sorghum cultivation under semi arid environment.

Keywords: Sorghum, nitrogen use efficiency, method of fertilizer application, growth, productivity and farm profitability

Introduction

Sorghum bicolor, Cholam (Great Millet) commonly known as jowar is a grass species which is widely grown for grain used for human food and animal feed. Grain sorghum is an important crop and considered as drought tolerant and suitable for drier regions (House, 1995) [9]. Sorghum is an important grain crop and cultivated in an area of 4.96 M ha, production of 4.95 M tonnes, and an average productivity of 998 kg ha^{-1} in India (Anonymous, 2018) [1]. Rajasthan is one of the major sorghum growing state in India with an area of 0.52 M ha (10.39% area of country), 0.30 M tonnes of production (6.07% production share at the national level), and productivity of 583 kg ha^{-1} (Anonymous, 2018) [1]. Considering the fact that most of the area in Rajasthan falls under arid and semiarid condition and insufficient and improper method and time of nitrogen application along with frequent drought stress with high temperature is more pronounced. High yielding sorghum is one of the grain crops which require more nitrogen fertilizer to reach optimal yields (Ashiono *et al*., 2005) [2]. Though sorghum can survive and perform better under adverse weather conditions, but yield can be greatly hampered by environmental stress and poor management.

Many studies have been conducted with application of different doses of nitrogen in sorghum. However, few studies have been conducted with method and time of application of nitrogen in semi arid condition of Rajasthan. Both the method and time of application of nitrogen requires careful management, but also contributes significantly in nitrogen use efficiency and improved crop performance. Hao *et al*. (2014) [7] reported that there is a high correlation between the rate of dry matter production and the application of different levels of nitrogen fertilizer in sorghum. Raun and Johnson (1999) [12] observed that more than 50% increase in the food production is attributed to the use of chemical fertilizers and nitrogen fertilizer contribution is maximum in this. Our aim to conduct this study is to access the impact of method and time of nitrogen application in improving nitrogen use efficiency and performance of grain sorghum.

Sigua *et al*. (2017) [14] observed that the erratic distribution of rainfall along with the farming practices such as nitrate leaching due to excessive application of nitrogen contributes towards poor crop yield. Zougmore *et al*. (2004) [15] observed that there is need to work out sound technologies for proper resource management including maximization of nitrogen use efficiency to achieve sustainable agricultural production. Duval (2018) [6] reported that increase of soil moisture and level of nitrogen resulted in the increase in sorghum yield.

Therefore, the objectives of present study were to determine the effects of different method and time of nitrogen application on nitrogen use efficiency and on growth behaviour, productivity and farm profitability of sorghum under semi-arid conditions.

Materials and Methods

A field experiment was conducted during three consecutive kharif season of 2015, 2016 and 2017 at research farm of Agricultural Research Sub Station, Diggi, Tonk (26° 34´ N, 75° 22´ E and 265 m altitude) under All India Coordinated Research Project (AICRP) on Sorghum to improve nitrogen use efficiency through method and time of application of nitrogen and impact on growth, productivity and economics of grain sorghum. The experimental site lies in the semi-arid eastern plain zone of Rajasthan (Zone IIIa), which is characterized by cold winters and hot summers. Occurrence of heat waves during May/June in summer season is quite common. The average annual rainfall of district is 500 mm of which about 90% is received during later half of monsoon season (June to September) with erratic distribution over time and space. The maximum temperature in summer is 45 ºC and minimum 26 ºC.

The soil of the experimental field was fine texture (clay loam) having pH of 8.2, low in organic carbon and nitrogen, high in available phosphorus and potassium. The experiment was laid down in factorial randomized block design and consists of five nitrogen scheduling treatments *viz*. N_1 (50% N at sowing + 50% N at 30 DAS), N_2 (50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage), N_3 (25% N at sowing + 50% N at 30 DAS + 25% N at boot leaf stage), N_4 (25% N at sowing + 50% N at 30 DAS + 15% N at boot leaf stage+10% at Grain filling stage), N_5 (25% N at sowing + 45% N at 30 DAS + 5% foliar spray at 45 DAS+15% N at boot leaf stage+10% at Grain filling stage), and two genotypes *viz* CSH-16 and CSV-20 and replicated thrice.

Field preparation included one deep ploughing by MB plough followed by two cross harrowing and planking. Two sorghum genotypes *viz* CSH-16 and CSV-20 were sown during second week of June with a recommended seed rate of 10 kg/ha. Crop was raised under irrigated condition and a total of five nitrogen scheduling treatments were applied. Proper crop protection measures were followed as and when required. The growth and yield attributes were recorded following the standard procedure by sampling from three places in each plot. The net plots (leaving the two border rows on the rows direction and half meter on opposite direction of the plots) of sorghum were harvested manually with sickles. The produce was left in field for sun drying for some days and after drying the biological yield was recorded and expressed in quintal/ha. After threshing the ear heads of each plot, the grains were properly cleaned, dried and weighed. The grain yield was expressed in quintal/ha. Straw yield was obtained by subtracting the grain yield from the weight of total biological yield for individual plots and was expressed in q/ha.

The net returns of each treatment were calculated by subtracting the total cost of cultivation from gross returns of each treatments and the benefit: cost (B:C) ratio was calculated by dividing the net returns by total cost of cultivation. All the data recorded from the field were analyzed with the help of analysis of variance for factorial randomized block design OPSTAT software. EXCEL software was used to draw diagrams and graphs.

Result and Discussion

Effect of method and time of nitrogen application on growth parameters of sorghum

The method and time of nitrogen application had significant effect on plant height of sorghum (Table 1). In sorghum, different method and time of nitrogen application led significant difference in plant height and significantly maximum value of plant height (223 cm) was recorded with application of nitrogen with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage. However, crop supplied nitrogen with the 50% N at sowing + 50% N at 30 DAS recorded statistically similar results for plant height. The method and time of nitrogen application also led significant effect on dry matter accumulation of sorghum (Table 1). The maximum value of dry matter accumulation (1750.3 g m^{-2}) was recorded with application of nitrogen with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage. However, crop supplied nitrogen with the 50% N at sowing + 50% N at 30 DAS recorded statistically at par results for dry matter accumulation. Among the cultivars, the maximum value of dry matter accumulation (1700.0 g m^{-2}) was recorded with CSV-20.

Since, nitrogen is the major nutrient also known as important constituents for cell division and elongation and its optimum availability resulted in higher plant growth. Higher availability of nitrogen might have improved photosynthetic area of plants that cumulatively contributed to higher dry matter accumulation. The results of this study are in close agreement with the results of Laftte *et al*., 1988 [10]; Hosein *et al*., 2007 [8]; Selahattin *et al*., 2002 [13].

Effect of method and time of nitrogen application on yield attributes of sorghum

The analysis of variance data indicated that method and time of nitrogen application had significant effect on yield attributes of sorghum (days to 50% flowering, number of grains/cob and test weight of sorghum (Table 2). The significantly maximum number of grains/cob (3136.0) and test weight (28.0 g) were recorded with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage. However, days to 50% flowering (67.2 days) were registered with 25% N at sowing + 50% N at 30 DAS + 25% N at boot leaf stage.

The cultivar CSV-20 resulted in minimum test weight (25.5 g) and number of grains/cob (2722.0 grains), while CSH-16 cultivar took less (66.3 days) days to 50% flowering than CSV-20 (67.8 days).
The optimum and balanced dose of nitrogen and method of application resulted in increased growth and development of plants and also improved the hydrological, physical, chemical, and biological properties of soil which provided an optimum environment for higher crop growth and development as reflected by higher yield attributes of plants (Maughan *et al*., 2012; Bean *et al*., 2013) [11, 3].

Table 1: Effect of method and time of nitrogen application on plant height and dry matter accumulation of grain sorghum (pooled over 2 years)

Treatments	Plant height (cm)	Dry Matter accumulation (g m^{-2})
	Harvest	Harvest
Nitrogen Scheduling		
N_1 (50% N at sowing + 50% N at 30 DAS)	214	1703.0
N_2 (50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage)	223	1750.3
N_3 (25% N at sowing + 50% N at 30 DAS + 25% N at boot leaf stage)	201	1686.5
N_4 (25% N at sowing + 50% N at 30 DAS + 15% N at boot leaf stage+10% at Grain filling stage)	195	1491.5
N_5 (25% N at sowing + 45% N at 30 DAS + 5% foliar spray at 45 DAS+15% N at boot leaf stage+10% at Grain filling stage)	206	1590.5
S.Em ±	4.1	24.9
CD (P=0.05)	12.2	74.7
Genotypes		
CSH-16	203	1688
CSV-20	213	1700
S.Em ±	1.54	25.7
CD (P=0.05)	4.6	77.1

Table 2: Effect of method and time of nitrogen application on yield attributes of grain sorghum (pooled over 2 years)

Treatments	days to 50% flowering	Test weight (g)	No. of grains /cob	Harvest Index
Nitrogen Scheduling				
N_1 (50% N at sowing + 50% N at 30 DAS)	69	25.9	2818	15.4
N_2 (50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage)	65.5	28.0	3136	15.9
N_3 (25% N at sowing + 50% N at 30 DAS + 25% N at boot leaf stage)	67.2	25.5	2834	15.4
N_4 (25% N at sowing + 50% N at 30 DAS + 15% N at boot leaf stage+10% at Grain filling stage)	67.1	25.1	2745	15.58
N_5 (25% N at sowing + 45% N at 30 DAS + 5% foliar spray at 45 DAS+15% N at boot leaf stage+10% at Grain filling stage)	66.6	25.0	2749	15.3
S.Em ±	0.77	0.63	63.2	2.8
CD (P=0.05)	2.3	1.8	189.6	NS
Genotypes				
CSH-16	66.3	26.4	3001.6	16.37
CSV-20	67.8	25.5	2722	15.08
S.Em ±	0.33	0.45	42.67	0.37
CD (P=0.05)	0.98	1.36	128	1.1

Effect of method and time of nitrogen application on crop productivity

The findings of present study revealed that method and time of nitrogen application had significant effect on sorghum productivity (Table 3). The mean maximum grain and straw yield of sorghum were recorded with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage were 24.55 q/ha and 131.61 q/ha which were 11.7% and 8.8% higher compared to control (50% N at sowing + 50% N at 30 DAS) respectively. Among the cultivars higher grain yield was recorded under CSH-16 (23.50 q/ha), while higher straw yield was recorded under CSV-20 (121.92 q/ha).
The total biomass yield 156.2 q/ha (grain yield + straw yield) was recorded higher with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage. 9.31% enhancement in the biomass yield of sorghum was recorded as compared to control (50% N at sowing + 50% N at 30 DAS). This enhancement in crop productivity might be due to higher plant growth, dry matter accumulation and yield attributes with the method and time of nitrogen application. The method and time of nitrogen application resulted in better utilization of nutrients uptake, soil moisture and balance in the soil temperature, soil porosity, soil aggregation, microbial activity and soil water holding capacity (Hao *et al*.,2014) [7].

Effect of method and time of nitrogen application on farm profitability

The highest cost of cultivation of grain sorghum was recorded under the treatment 50% N at sowing + 50% N at 30 DAS (Table 4). The significantly highest mean gross returns (₹89159) and net returns (₹62858) were observed with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage compared to control (₹80449 and ₹53722). The application of 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage increased the mean gross return by 10.83% and mean net returns by 17.01% over control (50% N at sowing + 50% N at 30 DAS).
The maximum B:C ratio (2.39) was reported with 50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage compared to control (2.01). Among the cultivars, the highest

cost of cultivation (₹26621), gross returns (₹82260) net returns (₹55639) and B:C ratio (2.09) was recorded with CSH-16. The higher crop productivity may be the principle reason for higher net returns under different method and time of nitrogen application. Similar results of higher farm profitability were also reported by Hosein *et al.*, 2007 [8]; Charles *et al.*, 2013 [4].

Table 3: Effect of method and time of nitrogen application on grain sorghum productivity potential (pooled over 2 years)

Treatments	**Grain Yield (q/ha)**	**Straw yield (q/ha)**	**Biomass yield (q/ha)**
Nitrogen Scheduling			
N_1 (50% N at sowing + 50% N at 30 DAS)	21.98	120.92	142.9
N_2 (50% N at sowing + 25% N at 30 DAS + 25% N at boot leaf stage)	24.55	131.61	156.2
N_3 (25% N at sowing + 50% N at 30 DAS + 25% N at boot leaf stage)	22.03	120.85	142.9
N_4 (25% N at sowing + 50% N at 30 DAS + 15% N at boot leaf stage+10% at Grain filling stage)	21.90	114.88	136.8
N_5 (25% N at sowing + 45% N at 30 DAS + 5% foliar spray at 45 DAS+15% N at boot leaf stage+10% at Grain filling stage)	21.38	111.27	132.7
S.Em ±	0.36	1.72	2.08
CD (P=0.05)	1.08	5.17	6.3
Genotypes			
CSH-16	23.50	119.17	142.7
CSV-20	21.07	121.92	143.0
S.Em ±	0.23	1.86	2.1
CD (P=0.05)	0.68	NS	6.3

Table 4: Effect of nitrogen scheduling on farm profitability (pooled over 3 years)

Treatments	**Cost of cultivation (□/ha)**	**Gross return (□/ha)**	**Net return (□/ha)**	**B:C ratio**
Nitrogen scheduling				
N1 (50+50)	26727	80449	53722	2.01
N2 (50+25+25)	26301	89159	62858	2.39
N3 (25+50+25)	26525	80370	53845	2.03
N4 (25+50+15+10)	26588	77904	51316	1.93
N5 (25+45+5+15+10)	26492	75501	49009	1.85
Cultivars				
CSH-16	26621	82260	55639	2.09
CSV-20	26566	79167	52601	1.98

Conclusion

Field experiment on grain sorghum was conducted to evaluate different method and time of nitrogen application. The results of this study proved that cultivation of grain sorghum with different method and time of nitrogen application resulted in significant improvement in the crop growth, productivity and overall profitability. Therefore, it can be concluded that different method and time of nitrogen application can be advocated as the most sustainable strategy for enhancing productivity and profitability of grain sorghum cultivation in semi arid conditions.

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