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Response of integrated nitrogen management and biofertilizer inoculation on yield and economics of *kharif* sorghum

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Abstract
Afield experiment was conducted at College of Agriculture, Nagpur during *kharif* season of 2016-17 on sorghum with the objectives to study the effect of integrated nitrogen management and *biofertilizer* inoculation on yield of *kharif* sorghum and to work out the economics in spilt plot design with five integrated nitrogen management treatments as main factor *viz.*, T_1- Control, T_2- 100% RDN through urea, T_3- 75% RDN through urea + 25% RDN through FYM, T_4- 50% RDN through urea + 50% RDN through FYM, T_5- 5 t FYM ha^{-1} and two biofertilizer inoculation as sub factor *viz.*, B_1- *Azotobacter* seed treatment and B_2- *Azospirillum* seed treatment replicated thrice making up total 30 number of plots. Treatment 50% RDN through urea + 50% RDN through FYM was found significantly superior over all the treatments in respect of yield and economics character *viz.*, length of earhead (29.00), grain yield plant^{-1} (40.00 g) and consequently produced higher grain yield (49.55 q ha $^{-1}$) as well as fodder yield (71.72 q ha $^{-1}$) at harvest and GMR (Rs. 99948), NMR (Rs. 72151) and B: C ratio (3.60) ratio was found maximum. The uptake of nitrogen in grain (72.28 kg ha^{-1}) and fodder (33.42 kg ha^{-1}) was significantly higher in 50% RDN through urea + 50% RDN through FYM. In biofertilizer inoculation, *Azospirillum* seed treatment was found significantly higher at all stages of crop growth in respect of yield and economics character *viz.*, length of earhead (27.27), grain yield plant^{-1} (37.87 g) and consequently produced higher grain (44.05 q ha $^{-1}$) as well as fodder yield (65.40 q ha $^{-1}$) and GMR (Rs. 89100), NMR (Rs. 63940) and B: C ratio (3.53) was found higher. The uptake of nitrogen in grain (61.81 kg ha^{-1}) and fodder (27.44 kg ha^{-1}) was significantly higher with *Azospirillum* seed treatment while available nitrogen was significantly higher with *Azotobacter* seed treatment.

Keywords: Sorghum, Integrated nitrogen management, biofertilizers, *Azospirillum*

Introduction
Sorghum is renowned as a Nature-care crop due to its remarkable resilience in challenging conditions like dry weather and high temperatures, setting it apart from other crops. It is primarily cultivated with minimal chemical treatments and limited use of pesticides, showcasing its potential to adapt naturally to its surroundings. Particularly valued for its ability to thrive in regions with scarce rainfall and elevated temperatures, such as semi-arid tropics and sub-tropical areas worldwide, Sorghum (*Sorghum bicolor* L.) stands as a significant cereal crop in India. Belonging to the Graminae family with a chromosome number of 2n=20, Sorghum is believed to have originated in Ethiopia and spread from Africa to India through various races. It is one of four major cereals of world followed by wheat, rice, maize in area and production. In India, Maharashtra holds the top position as the largest producer and consumer of sorghum, producing 5.8 million tonnes annually. Karnataka, Madhya Pradesh, and Andhra Pradesh are the following major sorghum producing states. Sorghum, formerly known as great millet, covers an extensive area of over 18 million hectares. One of the crucial limitations in Indian soil is the scarcity of nitrogen (N), which significantly impacts plant growth and development due to its metabolic and physiological requirements. To address this issue, biofertilizers play a vital role in increasing nutrient availability and enhancing productivity in an environmentally sustainable manner. Two free-living bacteria, Azotobacter and *Azospirillum*, are utilized for nitrogen fixation in the soil. Among the various reasons, less fertilization is the main reasons for low productivity of sorghum. Nitrogen, a crucial nutrient, significantly influences the growth and development of crops as it constitutes a major part of the plant body. According to Kulekci *et al*. (2009) [7], applying adequate nitrogen is essential to attain optimal yield and high-quality products. Biofertilizers, which contain beneficial

organisms, offer a cost-effective, eco-friendly, and renewable source of plant nutrients. These biofertilizers complement chemical fertilizers, making them ideal partners and essential supplements for sustainable agricultural practices.

Materials and Methods

During the kharif season of 2016-17, a field experiment took place at the Agronomy farm, College of Agriculture, Nagpur. The experiment followed a split plot design, with the main factor consisting of five integrated nitrogen management treatments, considering the recommended dose of nutrients as 80:40:40 kg NPK ha-1. *viz.*, T_1- Control, T_2- 100% RDN through urea, T_3- 75% RDN through urea + 25% RDN through FYM, T_4- 50% RDN through urea + 50% RDN through FYM, T_5- 5 t FYM ha^{-1} and two biofertilizer inoculations as sub factor *viz.*, B_1- *Azotobacter* seed treatment and B_2- *Azospirillum* seed treatment replicated thrice that made total number of experimental plots to 30. The soil of the experimental field was vertisol, slightly alkaline in nature (pH 7.60), low in available nitrogen and phosphorus, very high in available potassium and medium organic carbon. The crop variety CSH-9 was used with gross plot size of 5.4 m × 4.8 m and net plot size of 4.5 m × 4.5 m. In order to represent the treatment effect, periodic observations at 30 days interval was taken from five plants of sorghum from each net plot that were selected randomly, labeled properly.

Results and Discussion

The following results are derived from the experiments conducted during the year 2016-2017.

Yield Parameter

The data regarding grain yield $plant^{-1}$ and was significantly influenced by integrated nitrogen management and biofertilizer inoculation treatments.

A) Effect of integrated nitrogen management

The data revealed that, among all the treatments, application of 50% RDN through urea + 50% RDN through FYM recorded significantly higher length of the earhead $plant^{-1}$ (29.00), grain yield $plant^{-1}$ (40.00 and 49.55 q ha^{-1}) and fodder yield (71.72 q ha^{-1}) over 100% RDN through urea, 5 t FYM ha^{-1} and control treatments but was at par with 75% RDN through urea + 25% RDN through FYM at harvest. Control plot recorded least length of the earhead $plant^{-1}$ (24.00) and grain yield $plant^{-1}$ (34.17 and 33.92 q ha^{-1}). Test weight and Protein content (%) of grain was not influenced significantly due to integrated nitrogen management. A plausible explanation for the enhanced production of yield components and yield may lie in the provision of nutrients in a well-balanced measure and a readily accessible form. Manure provides all the necessary nutrients and enhances the soil's physical condition. This phenomenon can be credited to the consistent supply of nutrients throughout the entire growth period. The effectiveness of organic fertilizer becomes more noticeable when it is used in conjunction with organic manure (FYM). The enhanced vegetative growth and the balanced C: N ratio likely contributed to an increased synthesis of carbohydrates, ultimately leading to improved yield. The findings from this study align closely with the research conducted by Singh *et al*. (2009) [16], Patel *et al*. (2015) [12], and Nemade *et al*. (2017) [10].

B) Effect of biofertilizer

The grain yield was influenced significantly by biofertilizer application. *Azospirillum* seed treatment recorded significantly higher length of the earhead $plant^{-1}$ (27.27), grain yield $plant^{-1}$ (37.87 and 44.05 q ha^{-1}) and and fodder yield (65.40 q ha^{-1}) over *Azotobacter* seed treatment at harvest. Test weight and Protein content (%) of grain of sorghum showed non-significant differences due to biofertilizer applied to sorghum. "The enhanced crop yield resulting from *Azospirillum* seed treatment is likely a result of bacterial Indole-3-Acetic Acid (IAA) biosynthesis and secretion. These findings align closely with previous research conducted by Siddiqui *et al*. (2005) [14] and Patil (2014) [13]. *Azospirillum* enhances plant growth by producing phytohormones, which result in higher grain yield through improved photosynthate production and efficient translocation to reproductive parts. "The results obtained in this study closely correspond with the findings of Bhonde *et al*. (2002) [3], Kumar *et al*. (2002) [8], Nayak *et al*. (2002) [9], and Patil (2014) [13].

C) Interaction effects

Interaction effect of integrated nitrogen management and biofertilizer inoculation was found non-significant in respect of grain yield $plant^{-1}$ and grain yield q ha^{-1}.

Chemical studies

A) Effect of integrated nitrogen management

The data revealed that nitrogen uptake in grain (72.28 kg ha^{-1}) and fodder (33.42 kg ha^{-1}) was significantly higher in 50% RDN through urea + 50% RDN through FYM over 100% RDN through urea, 5 t FYM ha^{-1} and control treatments but was at par with 75% RDN through urea + 25% RDN through FYM at harvest. Control plot recorded least nitrogen uptake in grain (44.54 kg ha^{-1}) and fodder (17.97 kg ha^{-1}). "The observed phenomenon could be attributed to a more favorable nutritional environment in the rhizosphere, along with its efficient utilization within the plant system, resulting in improved nutrient translocation towards reproductive structures. These findings align closely with the research of Ketterings *et al*. (2007) [6], Singh *et al*. (2010) [17], and Singh *et al*. (2013) [18]."

B) Effect of biofertilizer

Azospirillum seed treatment recorded significantly higher nitrogen uptake at harvest over *Azotobacter* seed treatment. The data revealed that nitrogen uptake in grain (61.81 kg ha^{-1}) and fodder (27.44 kg ha^{-1}) was influenced significantly. This is might be due to the difference in grain and fodder yield. The results are in close accordance with the findings of Bhagchand and Gautam (2000) [2].

Interaction effects

Interaction effects of integrated nitrogen management and biofertilizer inoculation with respect nitrogen uptake kg ha^{-1} in grain and fodder were found to be non-significant.

Soil status studies

A) Effect of integrated nitrogen management

In treatment 5 t FYM ha^{-1} available nitrogen was highest (244.50) due to slow mineralization of nutrients through FYM and low yield which was at par with 100% RDN through urea at harvest. This might be due to probable more uptake of nutrient as indicated by higher grain and fodder yield. The investigation's outcomes align closely with the discoveries made by Singh *et al*. (2013) [18] in their study.

B) Effect of biofertilizer

Azotobacter seed treatment (232.67 kg ha^{-1}) recorded significantly higher available nitrogen at harvest over *Azospirillum* seed treatment (230.33 kg ha^{-1}). This might be due to lower yield and less nutrient uptake by crop.

C) Interaction effects

Interaction effects of integrated nitrogen management and biofertilizer inoculation with respect of available nitrogen were found to be non-significant.

Economics

A) Effect of integrated nitrogen management

Application of 50% RDN through urea + 50% RDN through FYM recorded significantly higher gross monetary returns, net monetary returns and benefit cost ratio (Rs. 99948 ha^{-1}, Rs. 72151 ha^{-1} and 3.60) was at par with 75% RDN through urea + 25% RDN through FYM (Rs. 91800 ha^{-1}, Rs. 66008 ha^{-1} and 3.56) at harvest. Control plot recorded least gross monetary returns, net monetary returns and B: C ratio (Rs. 69356 ha^{-1}, Rs. 47063 ha^{-1} and 3.11). This might be due to higher grain and fodder yield obtained under the treatment 50% RDN through urea + 50% RDN through FYM. This trend is mainly owing to the treatment effects on the grain and fodder yield. The results are in close accordance with the findings of Jadhav *et al.* (2012) [5], Singh *et al.* (2013) [18] and Patel *et al.* (2015) [12].

B) Effect of biofertilizer

Biofertilizer applied to sorghum was found significant in respect to gross monetary returns, net monetary returns and benefit: cost ratio. *Azospirillum* seed treatment recorded significantly higher gross monetary returns and net monetary returns (Rs. 89100 ha^{-1} and Rs. 63940 ha^{-1}) at harvest over *Azotobacter* seed treatment (Rs. 81561 ha^{-1} and Rs. 56656 ha^{-1}). This might be due to higher yield in *Azospirillum* and lesser yield in other treatment and due to higher grain yield obtained under these treatments as compared to cost involved under these treatments. The outcomes closely align with the research of Barik and Nag (2001) [1] and Singh *et al.* (2005) [16]. Treatment of *Azospirillum* registered higher benefit: cost ratio (3.53) than *Azotobacter* (3.26). This trend is mainly owing to the treatment effects on the grain and fodder yield.

C) Interaction effects

Interaction effects of integrated nitrogen management and biofertilizer inoculation was found to be non-significant in respect of gross monetary returns and net monetary returns

Table 1: Mean yield attributes and quality and nitrogen uptake, available N as influenced by different treatments

Treatments	Length of earhead at harvest	Grain yield plant-1 (g)	Grain yield (q ha^{-1})	Fodder yield (q ha^{-1})	Test weight (g)	Protein content (%)	Nitrogen uptake (kg ha^{-1})			Available N (kg) ha^{-1}
							Grain	Fodder	Total	
Integrated nitrogen management										
T_1 – Control	24.00	34.17	33.92	55.37	27.00	8.25	44.54	17.97	62.51	205.83
T_2- 100% RDN through urea	26.17	36.67	41.33	62.56	28.15	8.69	57.12	25.90	83.02	240.33
T_3- 75% RDN through urea + 25% RDN through FYM	27.67	37.33	45.33	68.00	29.07	8.92	64.68	29.83	94.51	236.33
T_4- 50% RDN through urea + 50% RDN through FYM	29.00	40.00	49.55	71.72	29.50	9.11	72.28	33.42	105.72	230.50
T_5- 5 t FYM ha^{-1}	25.83	35.17	40.62	57.69	27.70	8.42	54.76	19.93	74.69	244.50
SE (m) ±	0.83	0.93	1.32	2.32	0.52	0.18	2.24	1.45	3.61	1.71
CD at 5%	2.70	3.05	4.31	7.57	--	--	7.32	4.73	11.71	5.57
F test	Sig.	Sig.	Sig.	Sig.	NS	NS	Sig.	Sig.	Sig.	Sig.
Biofertilizer inoculation										
B_1- *Azotobacter* seed treatment	25.80	35.47	40.25	60.74	28.02	8.60	55.54	23.38	78.92	232.67
B_2- *Azospirillum* seed treatment	27.27	37.87	44.05	65.40	28.55	8.75	61.81	27.44	89.25	230.33
SE (m) ±	0.44	0.72	0.91	1.35	0.24	0.05	1.38	0.80	2.08	0.40
CD at 5%	1.39	2.27	2.86	4.27	--	--	4.36	2.52	6.54	1.26
F test	Sig.	Sig.	Sig.	Sig.	NS	NS	Sig.	Sig.	Sig.	Sig.
Interaction										
SE (m) ±	0.98	1.61	2.03	3.03	0.54	0.11	3.09	1.79	4.64	0.89
CD at 5%	--	--	--	--	--	--	--	--	--	--
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Cost of cultivation, gross monetary returns, net monetary returns and benefit: cost ratio as influenced by different treatments

Treatments	GMR (Rs ha^{-1})	COC (Rs ha^{-1})	NMR (Rs ha^{-1})	B: C ratio
Integrated nitrogen management				
T_1 – Control	**69356**	**22293**	**47063**	**3.11**
T_2- 100% RDN through urea	83784	23986	59798	3.49
T_3- 75% RDN through urea + 25% RDN through FYM	91800	25792	66008	3.56
T_4- 50% RDN through urea + 50% RDN through FYM	99948	27798	72151	3.60
T_5- 5 t FYM ha^{-1}	81763	25293	56471	3.23
SE (m) ±	2681	-	2681	-
CD at 5%	8743	-	8743	-
Biofertilizer inoculation				
B_1- *Azotobacter* seed Treatment	81561	24905	56656	3.26
B_2- *Azospirillum* seed Treatment	89100	25160	63940	3.53
SE (m) ±	1812	-	1812	-

CD at 5%	5708	-	5708	-
Interaction				
SE (m) ±	4051	-	4051	-
CD at 5%	NS	-	NS	-

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