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GROWTH, YIELD AND ECONOMICS OF SORGHUM AS INFLUENCED BY FERTILIZERS, ORGANIC MANURES AND BIO-FERTILIZERS

S. S. Patel[1], V. H. Surve[2], A. D. Raj[3], V. R. Jinjala[4] and P. M. Sankhala[5]

ABSTRACT

A field experiment was executed at College Farm, Navsari Agricultural University, Campus Bharuch, during the *kharif* season of 2024 to examine the impact of fertilisers, organic manures, and biofertilizers on the growth, yield, or economic viability of sorghum. The results demonstrated that the application of fertilizer (factor A), specifically 100% RDF, significantly enhanced growth parameters (plant height, ear head length, number of leaves plant^{-1} or internode length), yield attributes (test weight, grain yield, grain weight ear head^{-1}, or straw yield) as well as maximizing gross return (₹ 157,192 ha^{-1}), net return (₹ 120,096 ha^{-1}), and benefit-to-cost ratio (4.23). The application of organic manures (Factor B), specifically vermicompost at 2.5 t ha^{-1}, resulted significantly enhanced growth and yield attributes, with a grain yield of 1568 kg ha^{-1} and a straw yield of 9438 kg ha^{-1}. However, the highest gross profit of ₹ 119,402 ha^{-1}, net profit of ₹ 81,600 ha^{-1} and benefit-cost ratio of 3.16 were reached with the application of FYM at 5 t ha^{-1}. Application of biofertilizer (Factor C), specifically Azotobacter combined with PSB as a seed treatment (10 ml kg^{-1} seed), significantly enhanced growth parameters (plant height, number of leaves plant^{-1}, ear head length and internode length), yield attributes (test weight, grain weight ear head^{-1}, grain yield, or straw yield), as well as achieving maximum gross profit (130,916 ₹ ha^{-1}), net profit (98,054 ₹ ha^{-1}) and a benefit-to-cost ratio (3.98).

(Key words: Sorghum, vermicompost, biofertilizer, RDF, yield)

INTRODUCTION

Sorghum (*Sorghum bicolor L.*), an important cereal crop globally, serves as feedstock for many production systems and conditions, including food, feed, fiber, fuel, and biofuels. It has an exceptional capacity to yield a harvest in challenging circumstances, especially using significantly less water than other grain crops. It s a member of the Poaceae family. In terms of both area and output, it ranks 3rd in India, behind rice and wheat and fifth globally among cereals, behind wheat, maize, rice and barley. A crop that is grown extensively in Africa, America, Asia and many other regions of the world is sorghum. It thrives on marginal ground with moisture stress or excessive moisture conditions and has the strongest ability to tolerate drought. The expected global production of sorghum in 20232024 was 52.8 million tons. India has 4.4 million tons, Nigeria has 6.7 million tons, Brazil has 4.76 million tons, and the United States has 8.07 million tons. India produced 4.4 million tons of sorghum on 3.97 million hectares in 20232024, placing it fourth in the world in terms of overall production (Anonymous, 2023). In 20232024, it yielded 0.05 million tons year^{-1} on approximately 0.04 million hectares in Gujarat, achieving a productivity of 1378 kg ha^{-1}. (Oganja *et al.*, 2024).

Recommended dosage for sorghum cultivation was 80: 40: 40 kg N: P_2O_5:K_2O ha^{-1}. When recommended doses of fertilizers (RDF) are only added from inorganic sources, soil health deteriorates, pollution is caused and production costs rise. Because a large volume of organic manure is needed, which wont be available, applying purely organic sources to meet plant nutritional demands is also challenging. Thus, the integrated nutrient management (INM) concept in sorghum will be appropriate in all respects. Crop fertility, crop yield and crop quality are all enhanced by the integrated use of various plant nutrient sources, such as organic manure or bioinoculants, combined with chemical fertilizers. In light of factors above, the experiment growth, yield and economics of sorghum as influenced by fertilizers, organic manures and biofertilizers was conducted at College Farm, Navsari Agricultural University, Campus Bharuch, while the *kharif* 2024.

MATERIALS AND METHODS

The field trial was conducted in *kharif* 2024 at the College Farm, Navsari Agricultural University, Campus

1. P. G. Student, Dept. of Agronomy, COA, NAU, Bharuch - 392012 (Gujarat)
2. Asst. Professor, Dept. of Agronomy, COA, NAU, Bharuch - 392012 (Gujarat)
3. Professor, Dept. of Agronomy, COA, NAU, Bharuch - 392012 (Gujarat)
4. Asst. Research Scientist, MSRS, NAU, Surat - 395007 (Gujarat)
5. Asst. Professor, Dept. of Horticulture, COA, NAU, Bharuch - 392012 (Gujarat)

Bharuch under South Gujarat Zone II (Agro-ecological condition IV). The soil exhibited a mildly alkaline composition with a pH of 7.68, an electrical conductivity of 0.31 dSm^{-1}, and an organic carbon content of 0.32%. It contained a high concentration of accessible K_2O at 318 kg ha^{-1}, a low amount of nitrogen at 219 kg ha^{-1}, and a medium availability of P_2O_5 at 34.85 kg ha^{-1}. 3 levels of fertilizer (F_1: control (no RDF), F_2: 50% RDF, and F_3: 100% RDF), 2 levels of organic manure (O_1: FYM 5 t ha^{-1}, O_2: VC 5 t ha^{-1}), and 2 levels of biofertilizer (10 ml kg^{-1} seed) comprised the factorial randomized block design (FRBD), which was replicated 3 times with 12 treatment combinations. Seeds of the sorghum variety CSV-55 were evenly coated with PSB (10 ml kg^{-1} seed) and *Azatobacter* culture. A trench was dug at a distance of 45 cm × 15 cm to sow seeds. FYM was applied at the rate of 5 t ha^{-1}, and vermicompost at the rate of 2.5 t ha^{-1} during field preparation and before seeding in the open furrow. The treatment regimens were followed in order to apply the recommended fertilizer dose (RDF) for sorghum, which was 80:40:00 kg N:P: K ha^{-1}. During sowing, a half-dosage of N and a full dose of P were given; the remaining half-dose of N was applied 30 days following the starting date. The sources of N or P were urea and single super phosphate (SSP), correspondingly. 5 plants had randomly selected from the net plot and tagged in each plot to record yield characteristics like grain weight ear $head^{-1}$ and test weight, as well as growth metrics like plant height, number of leaves $plant^{-1}$, ear head length, or internode length. The net plot yield data for grain and straw were converted to hectares. Collected data have been analyzed as per the approach suggested by Panse and Sukhatme (1985). The gross realization, cost of production, net realization and B: C ratio was calculated. The harvest index was computed by utilizing subsequent formula.

$$\text{Harvest index (\%)} \quad \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

RESULTS AND DISCUSSION

Effect of fertilizers

The data given in Table 1 demonstrated that growth parameters had significantly impacted by fertilizer application at varying levels. The application of 100% RDF resulted significantly superior in plant height at 60 DAS and harvest (173.25cm and 255.33cm, correspondingly), greater number of leaves $plant^{-1}$ (12.36), ear head length (35.33 cm) and internode length (20.57 cm), followed by 50% RDF when compared with control. The application of nitrogen and phosphorus through chemical fertilizers may have contributed to the increase in plant height by increasing their availability, which in turn increased photosynthetic activity and caused the photosynthates to move from sources to sinks. Perhaps it induced meristematic cell activity and internode cell elongation, which led to a greater stem growth rate and, ultimately, sorghum growth. These findings matched with findings of Panwar *et al*. (2014) Tudu *et al*. (2023), and Pratibha *et al*. (2025). According to Panwar *et al*. (2014), 100% RDF (80:40:40 NPK kg ha^{-1}) increased sorghum plant height at harvest and dry matter accumulation $plant^{-1}$ at various stages. Tudu *et al*. (2023) found that 100% RDF + 10 t FYM ha^{-1} produced the highest plant height, number of leaves $plant^{-1}$ and ear head length $plant^{-1}$, comparable to 100% RDF + 5t FYM ha^{-1} and 75% RDF + 10 t FYM ha^{-1}. The plant height, number of leaves $plant^{-1}$ or number of branches $plant^{1}$ at harvest showed a significantly highest in treatment with application of 100% RDF + seed treatment with PSB + 2.5 t vermicompost $ha^{-1,}$ followed by 100% RDF + seed inoculation with PSB + 5 t vermicompost ha^{-1} reported by Pratibha *et al.* (2025).

The result about yield (Table 1) showed in comparing with other treatments, the application of 100% RDF followed by 50% resulting highest grain weight ear $head^{-1}$ (34.08g), grain yield (2048 kg ha^{-1}) or straw yield (10945 kg ha^{-1}) or harvest index (21.72 %) when compared with control. The N or P content of grain or straw suggests that the increase in yield qualities brought about through application of 100% RDF may have led to greater and more timely availability of N and P for plant usage. It is widely believed that nitrogen is an essential nutrient for plants. Chlorophyll is the main absorber of light energy required for photosynthesis, and it is a crucial component of this substance. Phosphorus fertilization also enhances physiological and metabolic functions, making it a form of energy currency that is used for phosphorylation, which in turn promotes vegetative and reproductive growth. Thus, 100% RDF application enhanced the growth parameters and yield characteristics, leading to increase sorghum grain and straw production. The current results are consistent with those of Naskar and Mallick (2023), Patel *et al*. (2013), Gabir *et al*. (2014), and Mishra *et al*. (2015). According to Patel *et al*. (2013), applying 100% RDF (80:40:00 NPK kg ha^{-1}) resulted noticeably higher grain yield. Particularly , Gabir *et al*. (2014) discovered that the 100% RDF treatment (50:25:25 NPK kg ha^{-1}) produced maximum grain or fodder yield. Mishra *et al*. (2015) found significantly higher grain yield or stover yield with the application of 150% RDF (120:60:60 NPK kg ha^{-1}), which was at par with the application of 100% RDF. Naskar and Mallick (2023) also observed that yields of both rice grain and straw were found to be increase with different treatment combinations. The amount of such increase in grain and straw yields recorded to be highest 7.77 t ha^{-1} (20.65 % over control) and 9.45 t ha^{-1} (14.82 % over control) respectively in the treatment TQ where 50% NPK as recommended + FYM H 5 t ha^{-1} + Zn @ 5 kg ha^{-1} + PSB @ 10 kg ha^{-1} was applied.

Findings presented in Table 2 clearly show that the application of 100% RDF and a B: C ratio of 4.23 provided the largest net return (₹ 120096 ha^{-1}). Higher grain or straw yields under these treatments, relative to the costs associated with them, are what caused the increase in net return. A similar view in the direction of the present finding was also expressed by Tudu *et al*. (2023). They reported that maximum net profit (₹ 48010 ha^{-1}) recorded from 100% RDF + 5 t FYM ha^{-1} but B: C ratio was 1.49 from 75% RDF.

Effect of organic manures

Data given in Table 1 suggest that various organic manures significantly impacted growth parameters. The application of vermicompost at 2.5 t ha^{-1} resulted in significantly higher plant height at 60 DAS or harvest (157.61 cm & 220.44 cm, correspondingly) and ear head length (29.11 cm), which was comparable to the application of FYM at 5 t ha^{-1}. This might be because vermicompost holds onto nutrients for a long period. In contrast, traditional manures dont provide enough macro- and micronutrients, particularly essential nutrients to plants, in a shorter amount of time. These results align with the findings of those reported by Elamin and Madhvi (2015) and Mallikarjun and Babalad (2021). Elamin and Madhvi (2015) observed that the vermicompost @ 2.5 t ha^{-1} resulted significant plant height increase over FYM and NSC (Neem seed cake) at 60 and 90 DAS. Organic production (OP) system resulted in significantly higher plant height (187.1cm), leaf area (27.6 dm^{-2}plant $^{-1}$), dry matter accumulation (DMA) in leaf (15.98 g plant^{-1}), stem (70.23 g plant^{-1}) and in reproductive parts (63.9 g plant^{-1}) and total dry matter production (TDMP) (150.1 g plant^{-1}) as compared to other farming systems evaluated by Mallikarjun and Babalad (2021).

The result pertaining to yield (Table 1) showed that organic manure treatment had a notable impact on yield attributes. Vermicompost at 2.5 tha^{-1} was found to increase grain weight ear head^{-1} (27.89 g) significantly, grain yield (1568 kg ha^{-1}) or straw yield (9438 kg ha^{-1}) or harvest index (17.08 %). A greater weight of ear head, grain, or straw yield appears to have resulted from the application of organic manure, which may have contributed to more plant nutrients, improved soil physical conditions, biological processes in the soil, and increased availability of photosynthesis, metabolites, and nutrients to develop reproductive structures. Similar results were found via Jat *et al*. (2013), Mallikarjun and Babalad (2021), Sallawar *et al.* (2023) and Nitesh *et al*. (2023). Significantly higher grain yield or harvest index with application of 10t FYM ha^{-1} + 100% NPK + Azatobacter & PSB recorded by Jat *et al*. (2013). Significantly higher grain yield (2389 kg ha^{-1}) produced with the organic production system (M) as compared to the INF (M) system (1766 kg ha^{-1}) and the SPNF (M) system (1994 kg ha^{-1}), which were on par with each other, reported by Mallikarjun & Babalad (2021). Sallawar *et al*. (2023) noted significantly higher grain yield, fodder yield, biological yield and harvest index with the treatment of 75% RDN by inorganic fertilizer + 25% RDN by vermicompost + seed treatment with PSB + *Azospirillum*. Nitesh *et al*. (2023) stated that significantly higher grain yield of rice (36.34 qha^{-1}) recorded with the application of 125 % RDF by chemical fertilizers + Verrnicompost @ 2 t ha^{-1} + Azotobacter + PSB seed treatment followed by treatment received 125 % through chemical fertilizers + Verrnicompost @ 2 t ha^{-1}.

Result illustrated in Table 2 demonstrated that organic manure treatment had a notable impact on maximum net return (81600 ¹ ha^{-1}) when FYM was applied with 5 t ha^{-1} along with B: C ratio of 3.16. The increase in net return was because of low cost of FYM as compared to vermicompost obtained under these treatments. A similar view in the direction of the present finding was also expressed by Sallawar *et al.* (2023). Applying 75% RDN by inor ganic fertilizer + 25% RDN by vermicompost + seed treatment with PSB + *Azospirillum* resulted in higher GMR (¹ 76,068 ha^{-1}), NMR (¹ 37,999 ha^{-1}), and B: C ratio (2.07), but was comparable to applying 75% RDN by FYM + seed treatment with PSB + *Azospirillum*.

Effect of biofertilizer

The results about yield (Table 1) showed significantly greater plant height at 60 DAS or harvest (158.83 cm and 222.94 cm, correspondingly) and the highest number of leaves plant^{-1} (11.44) observed when *Azatobacter* and PSB (10 ml kg^{-1} seed) were used as seed treatments. The microbial inoculants alternative inaccessible phosphorus (PSB) into plant-utilizable phosphorus or fix atmospheric nitrogen in the rhizosphere (*Azatobacter*), which both increase the availability of nutrients. The current outcomes are in cognizance with those of Sallawar *et al.* (2023) and Jat *et al.* (2013). Sallawar *et al.* (2023) recored maximum plant height, number of leaves plant^{-1} and length of internode with treatment of 75% RDN over inorganic fertilizer + 25% RDN by vermicompost + seed treatment with PSB + *Azospirillum*. Jat *et al.* (2013) recorded significantly increased plant height with the application of 10 t FYM ha^{-1}, 100% NPK and inoculation with *Azatobacter* + PSB.

The data given in Table 1 shows that biofertilizer use had a significant impact on sorghum yield attributes. Grain yield (1606 kg ha^{-1}), grain weight ear head^{-1} (28.00 g), straw yield (9539 kg ha^{-1}) and harvest index (17.56 %) were all significantly greater when *Azatobacter* and PSB were used as seed treatments (10 ml kg^{-1} seed). *Azatobacter* transforms nitrogen from the atmosphere into ammonia that the sorghum plant can utilize. It increases grain formation and promotes improved vegetative development by improving nitrogen nutrition. PSB converts the insoluble form of phosphate into forms that are accessible. It enhances the plant s ability to produce roots and use energy. It increases production by improving nutrient uptake, early flowering, and grain filling. *Azatobacter* and PSB applied together improve soil fertility, plant health and nutrient availability, which ultimately increase sorghum yield. This also confirms the outcomes of Jat *et al.* (2013) & Reddy *et al*. (2023). Jat *et al.* (2013) noted significantly higher grain yield or harvest index with the application of 10 t FYM ha^{-1} + 100% NPK + *Azatobacter* and PSB. Reddy *et al.* (2023) found maximum test weight, grain yield, or stover yield with application of 125% RDF + Biofertilizer consortium (*Azospirillum*, PSB or Potassium releasing bacteria in liquid form).

The findings demonstrated in Table 2 recorded significantly maximum net profit of ₹98054 ha^{-1} when biofertilizer (*Azatobacter* and PSB) was applied as a seed treatment along with B: C ratio of 3.98. Higher grain or straw yields under these treatments, relative to the costs associated with them, have essentially caused the increase in net profit. A similar view in the direction of the present finding was also expressed by Jat *et al.* (2013). The application of *Azatobacter*+PSB resulting significantly higher net profit (₹ 37,500 ha^{-1}) and B:C ratio (2.0) compared with other treatments.

Interaction effect

All interactions were found non-significant in respect of growth parameters, yield or yield attributes.

Table 1. Effect of fertilizer, organic manure and biofertilizer on growth and yield attributes of sorghum

Treatments	Plant height (cm)			Number of leaves plant^{-1} at harvest	Ear head length (cm)	Length of internode (cm)	Test weight (g)	Grain weight earhead^{-1} (g)	Harvest index (%)
	30 DAS	60 DAS	At harvest						
(A) Fertilizer level									
F_1 : Control (No RDF)	52.1	130.6	169.1	9.6	20.7	13.9	26.0	19.2	11.55
F_2 : 50% RDF	54.0	151.1	218.8	11.2	28.0	15.9	28.1	26.3	16.17
F_3 : 100% RDF	56.4	173.3	255.3	12.4	35.3	20.6	32.0	34.1	21.72
SE(m)±	1.2	4.3	4.9	0.3	0.8	0.5	0.7	0.8	0.43
CD at 5%	-	12.9	14.7	0.9	2.4	1.5	-	2.4	1.29
(B) Organic Manure									
O_1 : FYM @ 5 t ha^{-1}	53.7	145.7	208.4	10.7	26.9	16.3	28.4	25.2	15.88
O_2 : VC @ 2.5 t ha^{-1}	54.6	157.6	220.4	11.3	29.1	17.3	29.1	27.9	17.08
SE(m)±	1.0	3.5	4.0	0.2	0.7	0.4	0.6	0.6	0.35
CD at 5%	-	10.5	12.0	-	2.1	-	-	1.8	1.05
(C) Biofertilizer									
B_1 : No Biofertilizer	53.6	144.5	205.9	10.6	26.1	16.2	27.9	25.1	15.41
B_2 : *Azatobacter* and PSB	54.7	158.8	222.9	11.4	28.9	17.3	29.5	28.0	17.56
SE(m)±	1.0	3.5	4.0	0.2	0.7	0.4	0.6	0.6	0.35
CD at 5%	-	10.5	12.0	0.6	-	-	-	1.8	1.05
Interaction									
F x O									
SE(m)±	1.75	6.01	6.91	0.40	1.13	0.67	1.02	1.10	0.60
CD at 5%	-	-	-	-	-	-	-	-	-
O x B									
SE(m)±	1.43	4.91	5.64	0.32	0.92	0.55	0.83	0.90	0.49
CD at 5%	-	-	-	-	-	-	-	-	-
F x B									
SE(m)±	1.75	6.01	6.91	0.40	1.13	0.67	1.02	1.10	0.60
CD at 5%	-	-	-	-	-	-	-	-	-
F x O x B									
SE(m)±	2.47	8.50	9.77	0.56	1.59	0.95	1.44	1.56	0.85
CD at 5%	-	-	-	-	-	-	-	-	-

Table 2. Yield and economics of sorghum as influenced by fertilizer, organic manure and biofertilizer

Treatments	Yield		Cost of cultivation (₹ha^{-1})	Return (₹ha^{-1})		B:C ratio
	Grain	Straw		Gross	Net	
(A) Fertilizer level						
F_1 : Control (No RDF)	948	7743	32802	94176	61374	2.87
F_2 : 50% RDF	1488	8797	34949	120968	86019	3.46
F_3 : 100% RDF	2048	10945	37096	157192	120096	4.23
SE(m) ±	41.7	211.1				
CD at 5%	125	633				
(B) Organic Manure						
O_1 : FYM @ 5 t ha^{-1}	1421	8886	37802	119402	81600	3.16
O_2 : VC @ 2.5 t ha^{-1}	1568	9438	52802	128816	76014	2.44
SE(m) ±	34.0	172.4				
CD at 5%	102	517				
(C) Biofertilizer						
B_1 : No Biofertilizer	1383	8784	32802	117294	84492	3.58
B_2 : *Azatobacter* and PSB	1606	9539	32862	130916	98054	3.98
SE(m) ±	34.0	172.4				
CD at 5%	102	517				
Interaction						
F x O						
SE(m) ±	58.9	298.6				
CD at 5%	-	-				
O x B						
SE(m) ±	48.1	243.8				
CD at 5%	-	-				
F x B						
SE(m) ±	58.9	298.6				
CD at 5%	-	-				
F x O x B						
SE(m) ±	83.3	422.3				
CD at 5%	-	-				

*Selling price- Grain: 34₹ kg^{-1}, Straw: 8 ₹ kg^{-1}

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