International Journal of Agriculture and Nutrition 2025; 7(8): 103-107

ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(8): 103-107
www.agriculturejournal.net
Received: 18-06-2025
Accepted: 20-07-2025

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Effect of integrated nutrient management on growth parameters, yield attributes and yield of sorghum (*Sorghum bicolor* L.)

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DOI: https://www.doi.org/10.33545/26646064.2025.v7.i8b.275

Abstract
In order to investigate the effects of fertilizer, organic manure and biofertilizer on the growth and yield of sorghum, a field experiment was carried out in plot number 11 at College Farm, Navsari Agricultural University, Campus Bharuch, during the *kharif* 2024. A factorial randomized block design with three replications and twelve treatments was used to set up the field experiment. The treatments include three levels of fertilizer [F_1: control (no RDF), F_2: 50% RDF and F_3: 100% RDF], two levels of organic manure [O_1: FYM 5 t/ha, O_2: VC 2.5 t/ha] and two levels of biofertilizer [B_1: no biofertilizer, B_2: biofertilizer (*Azatobacter* + PSB) as seed treatment (10 ml/kg seed)]. In comparison to all other factors, the highest growth parameters (plant height, number of leaves per plant, ear head length and internode length) and yield attributes (test weight, grain weight per ear head, grain yield and straw yield) were recorded with 100% RDF, vermicompost @ 2.5 t/ha and biofertilizer (*Azatobacter* + PSB) as seed treatment (10 ml/kg seed).

Keywords: Sorghum, Vermicompost, Biofertilizer, RDF, Yield

Introduction
One of the top cereal crops in the world, sorghum (*Sorghum bicolor* L.) can be used as feedstock for a variety of production systems and conditions, including food, feed, fiber, fuel, and biofuels. Its 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 third 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 2023–2024 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 2023–2024, placing it fourth in the world in terms of overall production (CARP 23–24). During 2023–2024, it produced 0.05 million tons annually on an area of around 0.04 million hectares in Gujarat, with a productivity of 1378 kg/ha (Oganja *et al*., 2024) [9].

The recommended dosage for sorghum cultivation is 80 kg N, 40 kg P_2O_5, and 40 kg K_2O per hectare. 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 won't 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 and bioinoculants, in conjunction with chemical fertilizers.

In light of the aforementioned factors, the experiment "effect of integrated nutrient management on growth parameters, yield attributes, and yield of sorghum (*Sorghum bicolor* L.)" was conducted at Plot Number 11 College Farm, Navsari Agricultural University, Campus Bharuch, during the 2024 *kharif* season.

2. Material and Methods

The field trial was carried out in *kharif* 2024 at the College Farm, Navsari Agricultural University, Campus Bharuch, at Plot Number 11. Under the South Gujarat Zone II (agro-ecological condition IV), the trial site is situated. The clayey soil had a pH of 7.68, was somewhat alkaline, and contained 0.31 dS/m of EC and 0.32 percent organic carbon. The soil had a high level of accessible K_2O (318 kg/ha) and a low level of available N (219 kg/ha) and P_2O_5 (34.85 kg/ha), according to the nutrient analysis.

Using a factorial randomized block design (FRBD), the field experiment was set up with 12 treatment combinations that included three factors: three levels of fertilizer (F_1: control (no RDF), F_2: 50% RDF and F_3: 100% RDF), two levels of organic manure (O_1: FYM 5 t/ha, O_2: VC 5 t/ha), and two levels of biofertilizer (B_1: no biofertilizer, B_2: biofertilizer (*Azatobacter* + PSB) as seed treatment (10 ml/kg seed)] with three replications. Seeds of the sorghum variety CSV-55 were evenly coated with PSB (10 ml/kg seed) and *Azatobacter*. A trench was dug at a distance of 45 × 15 cm to sow seeds. FYM was applied at the rate of 5 t/ha and vermicompost at the rate of 2.5 t/ha 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 is 80:40:00 kg N:P: K ha^{-1}. At the time of sowing, a half-dose of nitrogen and a full dose of phosphorus were applied; the remaining half-dose of nitrogen was applied 30 days following the starting date. The sources of nitrogen and phosphorus were urea and single super phosphate (SSP), respectively.

In order to record growth metrics such as plant height, number of leaves per plant, ear head length, internode length and yield qualities like grain weight per ear head and test weight, five plants were randomly chosen from the net plot and tagged in each plot. The yield figures for grain and straw were taken from the net plot and translated to hectares. The Panse and Sukhatme approach was used to statistically examine the data.

3. Results and Discussion

3.1 Effect of fertilizer level

3.1.1 Growth parameters

Growth characteristics are significantly impacted by fertilizer application at varying levels. The application of 100% RDF resulted in noticeably increased plant heights at 60 DAS and harvest (173.25 cm and 255.33 cm, respectively) (F3).When 100% RDF was applied, a noticeably greater number of leaves (12.36), ear head length (35.33 cm), and internode length (20.57 cm) were observed (F3).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. Mishra *et al.* (2015) [6], Tudu *et al.* (2023) [16], Elamin and Madhvi (2015) [4] and Panwar *et al.* (2014) [11] all found similar findings.

3.1.2 Yield attributes

In comparison to all other treatments, the application of 100% RDF resulted in the highest grain weight per ear head (34.08 g), grain yield (2048 kg/ha) and straw yield (10945 kg/ha). The nitrogen and phosphorous content of grain and straw suggests that the increase in yield qualities brought about by the 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 an essential component of this substance. Phosphorous 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 increased sorghum grain and straw production. Patel and colleagues (2013) [12], Jat and colleagues (2013) [5], Deshmukh and colleagues (2014) [13] and Mishra and colleagues (2014) [17] observed similar findings.

3.2 Effect of organic manure

3.2.1 Growth parameters

The growth characteristics are significantly impacted by various organic manures. The application of vermicompost at 2.5 t/ha resulted in significantly higher plant height at 60 DAS and harvest (157.61 cm and 220.44 cm, respectively) and ear head length (29.11 cm), which was comparable to the application of FYM at 5 t/ha. This might be because vermicompost holds onto nutrients for a long period, whereas traditional manures don’t provide enough macro- and micronutrients, particularly essential nutrients, to plants in a shorter amount of time. These findings align with those of Tudu *et al.* (2023) [16], Sallawar *et al.* (2023) [15] and Elamin and Madhvi (2015) [4].

3.2.2 Yield attributes

Organic manure treatment has a notable impact on yield characteristics. Vermicompost at 2.5 t/ha was found to significantly increase grain weight per ear head (27.89 g), grain yield (1568 kg/ha), and straw production (9438 kg/ha).A greater weight of ear head, grain, and 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. According to Bhalerao *et al.* (2001) [1], Patidar and Mali (2004) [13], Jat *et al.* (2013) [5], Sallawar *et al.* (2023) [15] and Tudu *et al.* (2023) [16], these observations are in good accord with the findings.

3.3 Effect of biofertilizer

3.3.1 Growth parameters

Significantly greater plant heights at 60 DAS and harvest (158.83 cm and 222.94 cm, respectively) and the highest number of leaves per plant (11.44) were observed when *Azatobacter* and PSB (10 ml/kg 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. Nemade *et al.* (2017) [8], Sallawar *et al.* (2023) [16] and Jat *et al.* (2013) [5] all reported similar results.

3.3.2 Yield parameters: Biofertilizer use has a considerable impact on sorghum yield parameters. Grain yield (1606 kg/ha), grain weight per ear head (28.00 g), and straw production (9539 kg/ha) were all significantly greater when *Azatobacter* and PSB were used as seed treatments (10 ml/kg 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 improved nutrient uptake, early flowering, and grain filling. *Azatobacter* and PSB applied together improve soil fertility, plant health, and nutrient availability, which increases sorghum yield. Others who have reported similar results include Jat *et al.* (2013) [5], Nemade *et al.* (2017) [8], Reddy *et al.* (2023) [14] and Sallawar *et al.* (2023) [16].

Table 1: The effect of fertilizer, organic manure and biofertilizer on sorghum plant height (cm)

Treatments	Plant height (cm)		
	30 DAS	60 DAS	Harvest
(A) Fertilizer level			
F_1 (Control no RDF)	52.08	130.58	169.08
F_2 (50% RDF)	54.00	151.17	218.83
F_3 (100% RDF)	56.42	173.25	255.33
S.Em. ±	1.24	4.25	4.88
CD at 5%	NS	17.62	20.25
(B) Organic Manure			
O_1 (FYM @ 5 t/ha)	53.72	145.72	208.39
O_2 (VC @ 2.5 t/ha)	54.61	157.61	220.44
S.Em. ±	1.01	3.47	3.99
CD at 5%	NS	14.39	16.54
(C) Biofertilizer			
B_1 (No Biofertilizer)	53.61	144.50	205.89
B_2 (BF: *Azatobacter* and PSB)	54.72	158.83	222.94
S.Em. ±	1.01	3.47	3.99
CD at 5%	NS	10.18	11.69
Interaction	NS	NS	NS
CV (%)	7.90	9.71	7.89

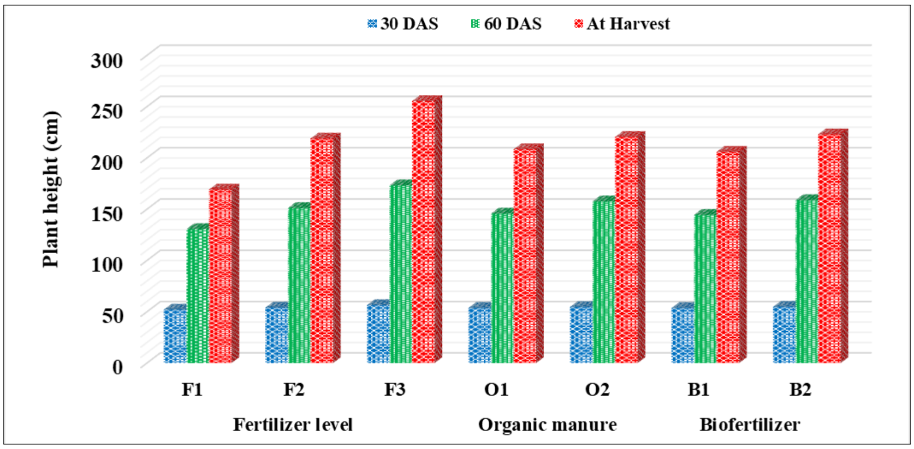

Fig 1: Sorghum plant height (cm) as influenced by fertilizer amount, biofertilizer and organic manure

Table 2: Leaf count per plant, ear head length, and sorghum internode length as affected by fertilizer, organic manure and biofertilizer

Treatments	Number of leaves/plant at harvest	Ear head length (cm)	Length of internode (cm)
(A) Fertilizer level			
F_1 (Control no RDF)	9.58	20.67	13.89
F_2 (50% RDF)	11.17	28.00	15.89
F_3 (100% RDF)	12.36	35.33	20.57
S.Em. ±	0.28	0.80	0.47
CD at 5%	1.16	3.31	1.96
(B) Organic Manures			
O_1 (FYM @ 5 t/ha)	10.72	26.89	16.27
O_2 (VC @ 2.5 t/ha)	11.33	29.11	17.30
S.Em. ±	0.23	0.65	0.39
CD at 5%	NS	2.70	NS
(C) Biofertilizer			
B_1 (No Biofertilizer)	10.61	26.06	16.24
B_2 (BF: *Azatobacter* and PSB)	11.44	28.94	17.27
S.Em. ±	0.23	0.65	0.39
CD at 5%	0.67	NS	NS
Interaction	NS	NS	NS
CV (%)	8.78	9.86	9.77

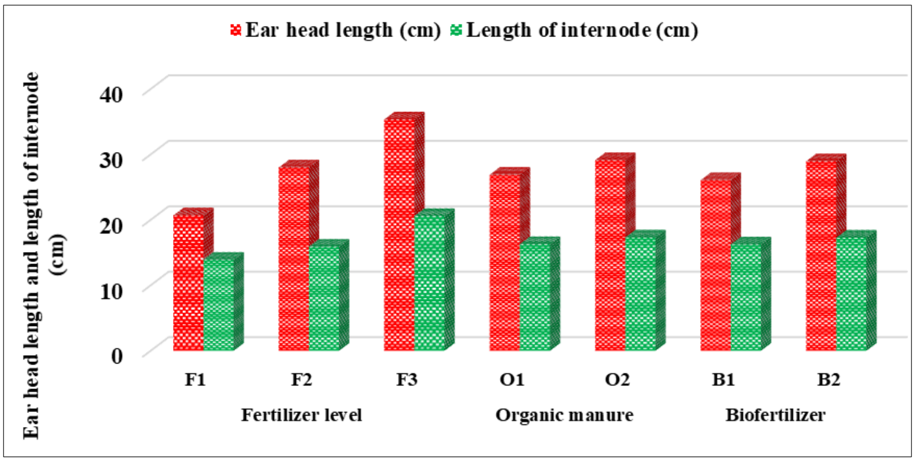

Fig 2: Effects of fertilizer amount, organic manure, and biofertilizer on sorghum's ear head length and internode length (cm)

Table 3: Sorghum test weight and grain weight per ear head as affected by fertilizer, organic manure and biofertilizer

Treatments	Test weight (g)	Grain weight/ear head (g)
(A) Fertilizer level		
F_1 (Control no RDF)	26.03	19.17
F_2 (50% RDF)	28.13	26.33
F_3 (100% RDF)	31.95	34.08
S.Em. ±	0.72	0.78
CD at 5%	NS	3.24
(B) Organic Manure		
O_1 (FYM @ 5 t/ha)	28.36	25.17
O_2 (VC @ 2.5 t/ha)	29.05	27.89
S.Em. ±	0.59	0.64
CD at 5%	NS	2.64
(C) Biofertilizer		
B_1 (No Biofertilizer)	27.94	25.06
B_2 (BF: *Azatobacter* and PSB)	29.48	28.00
S.Em. ±	0.59	0.64
CD at 5%	NS	1.87
Interaction	NS	NS
CV (%)	8.69	10.19

Table 4: The effects of fertilizer, organic manure and biofertilizer on sorghum's grain yield, straw yield and harvest index

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
(A) Fertilizer level			
F_1 (Control no RDF)	948	7743	11.55
F_2 (50% RDF)	1488	8797	16.17
F_3 (100% RDF)	2048	10945	21.72
S.Em. ±	41.65	211.14	0.43
CD at 5%	173	876	1.77
(B) Organic Manure			
O_1 (FYM @ 5 t/ha)	1421	8886	15.88
O_2 (VC @ 2.5 t/ha)	1568	9438	17.08
S.Em. ±	34.01	172.39	0.35
CD at 5%	141	715	1.44
(C) Biofertilizer			
B_1 (No Biofertilizer)	1383	8784	15.41
B_2 (BF: *Azatobacter* and PSB)	1606	9539	17.56
S.Em. ±	34.01	172.39	0.35
CD at 5%	100	506	1.02
Interaction	NS	NS	NS
CV (%)	9.66	7.98	8.95

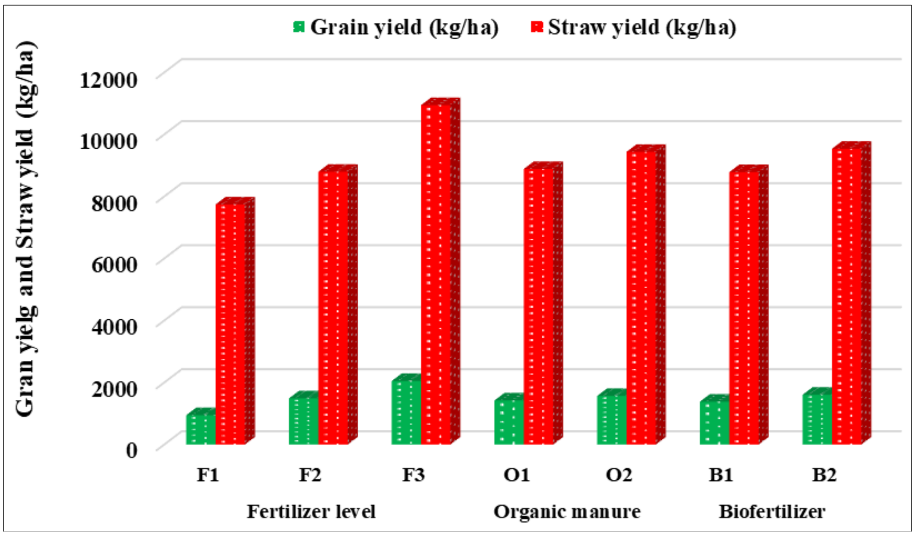

Fig 3: Sorghum grain and straw yields (kg/ha) as influenced by fertilizer amount, organic manure and biofertilizer

4. Conclusion

When combined with chemical fertilizers, the integrated use of several plant nutrition sources, such as organic manure and bioinoculants, improved sorghum growth, productivity, and yield. Based on the current study, it can be said that applying 100% RDF in combination with FYM at 5 t/ha or vermicompost at 2.5 t/ha and biofertilizers like *Azatobacter* and PSB as a seed treatment (10 ml/kg seed) led to noticeably higher sorghum growth parameters and yield attributes.

5. Acknowledgments

Sincere thanks are extended by the authors to the Department of Agronomy at N.A.U., Bharuch Campus (Gujarat), for supporting the research and providing the required facilities.

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