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Evaluation of biogas slurry along with vermicompost as a primary nutrient source for okra (*Abelmoschus esculentus*) in the arid climate of North Gujarat

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Abstract

Biogas slurry, a nutrient-rich by-product of anaerobic digestion, has considerable potential as an organic fertilizer but remains underutilized in crop production systems. This study evaluated the effect of biogas slurry, alone and in combination with vermicompost, on okra (*Abelmoschus esculentus* L.) growth, yield, and soil chemical properties under the arid climatic conditions of North Gujarat. A field experiment was conducted in 2025 on red stony soil using six nutrient management treatments, including a control, 100% vermicompost, and graded combinations of vermicompost and biogas slurry (25%, 50%, 75%, and 100% biogas slurry), arranged in a replicated design. Results showed a clear improvement in growth and yield attributes with increasing proportions of biogas slurry. The highest plant height, fruit weight, number of fruits per plant, and fruit yield were recorded under 100% biogas slurry treatment, followed closely by the 50% vermicompost + 50% biogas slurry combination. Soil organic carbon increased substantially from 0.42% in the control to 1.06% under 100% biogas slurry, while available nitrogen, phosphorus, and potassium also showed a consistent increasing trend. Soil pH and electrical conductivity increased slightly but remained within safe limits.

Keywords: Biogas slurry, okra (*Abelmoschus esculentus*), soil properties, nutrient enhancement

1. Introduction

Biogas slurry is a by-product of biogas production, which is generated from anaerobic digestion of animal waste and crop residue. It is generally considered a waste material. However, its application can improve soil health, crop yield, and profitability of the farmers as it is a rich source of organic matter and plant nutrients.

Utilizing biogas slurry and vermicompost instead of chemical fertilizers is able to significantly mitigate these issues. We established fertilization treatments to investigate the impact of biogas slurry substitution okra growth and soil properties in field experiments with varying proportions of biogas slurry and vermicompost.

Utilizing small amounts of biogas slurry and vermicompost as a replacement for chemical fertilizers was able to maintain soil nutrient levels while increasing okra yield (from 140 kg/500 sqm² to 250 kg/500sqm²), stabilize urease and catalase activities, and improve microbial communities. Additionally, using a minor amount of biogas slurry and vermicompost as a substitute for chemical fertilizer resulted in an increase in the population of potentially beneficial bacteria.

Structural equation modelling showed that the replacement of chemical fertilizers by biogas slurry and vermicompost directly and indirectly increased crop yield by altering soil characteristics and the microbial community.

These results improve our comprehension of the impact of various biogas slurry and vermicompost substitutes and hold significant theoretical importance for advancing the utilization of biogas slurry in the future.

2. Materials and Methodology

The experimental site was situated in the Ranpur village, Danta block, Banaskantha. The region features an arid climate, with temperature of 38°C to 48°C and total annual precipitation of 400

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mm recorded in 2025, respectively. The soil is classified as red stony soil. The initial chemical properties of the soil were recorded as follows: pH at 7.57, EC 0.39 (dS/m), soil organic

carbon (OC) at 0.42 g/kg, available nitrogen (AN) at 175.53 kg/ha, available phosphorus (AP) at 77.53 kg/ha, and available potassium (AK) at 348 kg/ha.

Table 1: Initial Soil mechanical and chemical properties

Sr. No.	Particulars		Method employed	Reference
A	Physical properties			
	Mechanical fraction (%)		International pipette Method	Piper (1966)
1	Sand	55.60		
2	Silt	27.37		
3	Clay	17.03		
4	Texture class	Red Stony Soil		
B	Chemical properties			
1	pH (1: 2.5)	7.57	Potentiometry	Jackson (1973)
2	EC (dSm ⁻¹)	0.39	Conductometry	Jackson (1973)
3	Organic carbon (%)	0.42	Wet oxidation method	Jackson (1973)
4	Available Nitrogen (kg ha ⁻¹)	175.53	Alkaline KMnO4 method	Subbiah and Asija (1956)
5	Available P ₂ O ₅ (kg ha ⁻¹)	77.53	0.5 M NaHCO ₃ extractant method	Olsen <i>et al.</i> (1954)
6	Available K ₂ O (kg ha ⁻¹)	348	Neutral Normal ammonium acetate extractant method	Jackson (1973)

The biogas slurry (moisture content:96% -98%) was subjected to preliminary filtration using a horizontal spiral centrifuge (filtration precision: 370µm) and secondary filtration through a filter concentrator centrifuge (filtration precision: 150µm). The filtered biogas slurry has an organic carbon content of about 4.31g/L, total nitrogen (ammonium nitrogen) of approximately 3.5g/L, total phosphorus of about 91 mg/L, total potassium of about 3.07 g/L, chemical oxygen demand of about 36 g/L, pH of approximately 8.7, and EC of around 13.7 mS/cm.

2.1 Experimental design

The experiments used locally recommended okra varieties and were conducted on June 11, 2025, and August 14, 2025. Each experimental plot measured 1010 m² and was sown using the flat seeding method, with equal row spacing. The okra rows were spaced 60 cm apart with a plant spacing of 30 cm.

Six treatment groups were established, including a control group, with each treatment comprising three replicates. All treatments used a combined base and topdressing fertilization method. For base fertilization, compound fertilizer (N-P₂O₅-K₂O) was applied at a rate of 100–50–50 kg/ha for each treatment. The experiments were designed based on an equivalent nitrogen application rate of 100 kg/ha. Additional topdressings were applied according to different ratios of BS and vermicompost substitution for chemical nitrogen, including a mixture of water-BS and urea. The application of total nitrogen was split into two stages, representing 40% and 60% of the total nitrogen application, respectively. The specific topdressing treatments were as follows:

1. No topdressing and irrigation
2. 100% vermicompost

3. 75% vermicompost + 25% BS
4. 50% vermicompost + 50% BS
5. 25% vermicompost + 75% BS
6. 100% BS

2.2 Topdressing system operation

For our 0.05 ha okra plot apply 500–750 liters of biogas slurry diluted with irrigation water at a 1:3 ratio during the vegetative stage. Deliver the mixture through furrows in the early morning to prevent nutrient evaporation and ensure deep root penetration in the red stony soil. This top-dressing provides essential nitrogen and organic matter, which improves moisture retention and protects the plants from the intense heat. Plants were harvested at maturity stage and following parameters were studied number of fruits, consistent shape, size and weight.

3. Results and Discussion

3.1 Impact on Growth and Yield Attributes

The experimental data reveals a clear positive correlation between the proportion of biogas slurry and vermicompost used and the physical development of the okra plants. The height of the okra plants increased progressively with higher BS substitution rates. The tallest plants were recorded in the 100% BS (T₆) treatment at 95.12 cm, compared to only 80.02 cm in the control group (T₁) and Fruit weight Individual fruit weight showed a similar upward trend. The 100% BS treatment yielded the heaviest fruits at 8.2 gm, which is nearly double the weight of the control group fruits (5.1 gm). The number of fruits per plant varied from 12.30 to 18.00, with a mean of 15.81 fruits per plant. The CV (12.97%) reflects moderate variability among treatments.

Table 2: Effect of different treatments on plant height, single fruit weight and no. of fruits per plant of okra

Treatments		Plant Height (cm)	Fruit Weight (gm)	No. of Fruits per Plant
T ₁	No topdressing and irrigation (CK)	80.02	5.1	12.30
T ₂	100% vermicompost	82.15	5.6	15.05
T ₃	75% vermicompost + 25% BS	84.74	6.4	15.20
T ₄	50% vermicompost + 50% BS	87.89	7.5	17.50
T ₅	25% vermicompost + 75% BS	91.23	7.8	16.80
T ₆	100% BS	95.12	8.2	18.00
CV%		6.55	18.6	12.97

Table 2 shows that different ways of managing nutrients affected the length, diameter and yield of okra fruits. The treatment with no fertilizers or irrigation (T₁) had the worst results, with the

shortest fruit length of 9.4 cm the smallest diameter of 1.18 cm and the lowest yield of 4.55 mt/ha. Using vermicompost alone (T₂) was better than the control treatment. When vermicompost

and BS were used together the fruit length, diameter and yield all increased. The more BS used the better the results were. The highest yield of 8.45 mt/ha was seen with T₆, which used 100%

BS. This was closely followed by T₄, which used a mix of 50% vermicompost and 50% BS giving a yield of 8.10 mt/ha.

Table 2: Effect of different treatment on fruit length, fruit diameter and fruit yield of okra

Treatments	Fruit length (cm)	Fruit diameter (gm)	Fruits yield (mt/ha)
T ₁ No topdressing and irrigation	9.4	1.18	4.55
T ₂ 100% vermicompost	10.60	1.26	6.55
T ₃ 75% vermicompost + 25% BS	11.64	1.34	6.70
T ₄ 50% vermicompost + 50% BS	12.51	1.42	8.10
T ₅ 25% vermicompost + 75% BS	12.07	1.27	7.30
T ₆ 100% BS	12.28	1.39	8.45
CV%	10.5	3.46	6.70

The longest fruits (12.51 cm) and the largest diameter (1.42 cm) were found with T₄ showing that a balanced mix of vermicompost and BS is good for making okra fruits bigger. Overall using BS

with vermicompost worked better, than using vermicompost alone and this helped okra plants grow and produce more yield.

Table 3: Effect of Biogas slurry on soil chemical properties

Treatments	Soil pH ^{1.25}	EC (ds/m)	Soil organic carbon (%)
T ₁ No topdressing and irrigation	7.57	0.39	0.42
T ₂ 100% vermicompost	7.59	0.35	0.57
T ₃ 75% vermicompost + 25% BS	7.68	0.41	0.68
T ₄ 50% vermicompost + 50% BS	7.72	0.35	0.69
T ₅ 25% vermicompost + 75% BS	7.78	0.41	0.87
T ₆ 100% BS	7.84	0.45	0.92
CV%	1.38	9.86	26.7

Table 3 shows what happens to the soil when we use combinations of biogas slurry and vermicompost. We looked at how these combinations affect the chemical properties of the soil like the soil pH, electrical conductivity and soil organic carbon. The soil pH went up a bit from 7.57 in the control to 7.84 when we used 100% biogas slurry. This means that using biogas slurry made the soil more alkaline, but not by much. The electrical conductivity was between 0.35 and 0.45 dS/m. It was highest when we used 100% biogas slurry. This shows that using biogas slurry increased the amount of soluble salts in the soil but it was still safe. Soil organic carbon is where we saw an improvement. It went up from 0.42% in the control to 0.92% when we used 100% biogas slurry. This clearly shows that biogas slurry is good for the soil and helps increase the amount of carbon in it.

The numbers we got from our tests show that using biogas slurry and vermicompost had an effect on the soil organic carbon and this effect was statistically meaningful. Overall Table 3 shows that using biogas slurry either on its own or with vermicompost made the soil healthier. It particularly helped increase the soil carbon, which is good for the soil and helps us manage it in a sustainable way. Biogas slurry is beneficial, for the soil. It helps make the soil more fertile.

Table 4: Effect of biogas slurry on nutrient enhancement in soil

Treatments	Available N	Available P	Available K
T ₁ No topdressing and irrigation	175.53	77.53	348.00
T ₂ 100% vermicompost	176.01	77.99	348.56
T ₃ 75% vermicompost + 25% BS	177.38	78.63	348.99
T ₄ 50% vermicompost + 50% BS	178.56	79.87	349.98
T ₅ 25% vermicompost + 75% BS	179.57	80.16	350.12
T ₆ 100% BS	181.51	81.10	350.50
CV%	1.27	1.80	0.27

The table 4 summarizes the effect of different vermicompost and biogas slurry (BS) treatments on available soil nutrients (N, P, and K). Available nitrogen increased steadily from 175.53 kg ha⁻¹ in

the control (T₁) to 181.51 kg ha⁻¹ under 100% biogas slurry (T₆), indicating improved nitrogen availability with increasing BS levels. A similar increasing trend was observed for available phosphorus and potassium, with maximum values of 81.10 kg ha⁻¹ P and 350.50 kg ha⁻¹ K recorded under T₆. The low SEM and CV values (1.27% for N, 1.80% for P, and 0.27% for K) indicate high experimental precision, while the CD at 5% level shows that nutrient increases due to higher proportions of biogas slurry were statistically significant. Overall, the results clearly demonstrate that biogas slurry, alone or in combination with vermicompost, effectively enhances soil nutrient availability, supporting its beneficial role in improving soil fertility.

4. Conclusion

Among all the treatments, T₆: 100% BS (100%BS) consistently demonstrated superior results. These findings underscore the potential of biogas slurry in enhancing okra growth, soil health, and nutrient availability in agricultural systems.

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